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INVESTIGATIONS ON THE TRANSPORTATION OF SEED POTATOES FROM NEBRASKA TO TEXAS AND ALABAMA

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INTRODUCTION

The two transportation tests covered by this report were made as a result of several seasons of experimental work to determine the effects of holding temperatures prior to planting on the emergence and yield of Nebraska seed potatoes when they were planted in the early potato districts of Texas and Alabama. These studies were conducted by representatives of the Department of Horticulture of the Nebraska Agricultural Experiment Station in cooperation with Branch Experiment Stations at Alliance, Nebraska, Fairhope, Alabama, and Weslaco, Texas. They were concerned largely with means of shortening the dormant period of Bliss Triumph potatoes in order to obtain more rapid emergence. The studies indicated that a period at a temperature somewhat higher than that to which the potatoes were exposed in the storage cellars was desirable for potatoes which were to be planted in the South during December, January, and early February.

Since the seed potatoes are moved from the storage cellars in Nebraska to the southern potato districts prior to the mid-winter and early spring planting season at a time when transit temperatures are uncertain, variable, and sometimes rather low, it appeared that some benefit might be derived from more adequate heating and air circulation in the refrigerator cars during the transit period.

The two transportation tests (Nebraska-1-1942 and Nebraska-1-1943) reported herein were planned and conducted (1) to determine the temperature conditions under which potatoes are commonly transported, (2) to ascertain the possibilities of raising or maintaining load temperatures by means of automatic heaters and forced air circulation as compared with the commonly used charcoal heaters and natural air circulation, and (3) to determine the effect of these temperature conditions on the field performance of selected samples of potatoes from each of the test cars.

1/ This work was initiated at the request of H. O. Werner of the Nebraska Agricultural Experiment Station as a result of findings in storage experiments with seed potatoes that were conducted during the last few years. He was responsible for planning the storage phases, prescribing the shipping temperatures to be provided, and arranging for the test loads of potatoes. In addition he rendered valuable assistance at the time the test cars were loaded.

The transportation tests were under the general direction of D. F. Fisher, Principal Horticulturist, in charge of Investigations on Handling, Transportation and Storage of Fruits and Vegetables, U. S. Department of Agriculture.

Only the transit phases of the problem are covered in this report. A more comprehensive report covering the effect of storage and transit temperatures on the emergence and yield of potatoes will be issued when all of the data are available.

METHODS

Cars and Heaters

The general outline of the tests is shown in Tables 1 and 2. Five cars equipped with circulating fans and four standard cars were used in each test. The circulating fans were the latest type Preco floor fan, which operated by a friction drive from the car wheel and moved the air toward the bottom bulkhead opening, through the bunker, and out the top bulkhead opening over the load.

In the first test only two cars were equipped with thermostatically controlled alcohol heaters, as the highest thermostat setting was 45° F. on the F.G.E. automatic alcohol heaters used and consequently they could not be used in the cars to be shipped at 65°. In addition, the F. G. E. automatic heaters were equipped with a steam-turbine-operated blower fan, which forced heated air through a flexible pipe beneath the floor rack. As the direction of air movement by the heater fan was opposite to that created by the Preco floor fan, the F. G. E. heaters were not adapted for use in fan-equipped cars. One F. G. E. automatic heater was placed in each bunker of cars G and K, which were standard cars, carried at low temperatures.

Seven cars in the first test were equipped with charcoal heaters. These were small-model Simplex heaters with 20-pound fuel magazine, 14-inch fire pot, and manually operated draft slide. The heaters were placed on the drip pans in the bunkers. As there appeared to be a possibility that the increased draft caused by operation of the circulating fans would cause excessive burning in the charcoal heaters, a metal baffle was placed around the base of each heater in fan cars. The baffles consisted of metal rings about 4 inches in height and 4 inches larger in diameter than the base of the heater. These were held in place by 2-inch blocks placed at intervals between the heater and the ring baffle.

In the second test five fan cars and two standard cars were equipped with P.F.E. thermostatically controlled alcohol heaters. These heaters had thermostatic settings up to 75° and were without air-circulating devices, so they could be used in fan cars and in loads to be carried at the higher temperature. Cars L, N, R, and S, in which the potatoes were to be kept warm or to be warmed in transit, had an alcohol heater placed in each bunker; whereas cars M, P, and T, which were to be carried at lower temperature, had an alcohol heater in only the front bunker of each car.

One charcoal heater was placed in each bunker of cars V and X. These were Klauer-Baxter Junior "Take-Down" heaters with a magazine capacity of 23 pounds of fuel and a 10-inch fire pot. They were placed on the ice grates in the bunkers.

Table 1. Plan of Experiment, Seed Potato Transportation Test, Scottsbluff, Nebraska to Russelltown, Texas - December 14 to 21, 1942.

TEST	CAR NO.	EXPERIMENT 1/	STORAGE TREATMENT	SHIPPING TREATMENT	CAR TYPE	GROWER
A	WFE 66486	WW	Moved to warm room at average temp. of 55-60° for 4 weeks before loading.	Shipped warm; charcoal heaters. Held near 65° F.	Preco Fans	Ehrman
B	WFE 66463	WC	do.	Shipped cool; charcoal heaters. Held near 38°.	do.	do.
C	BRE 74445	CW	Kept cool until shipped.	Shipped warm; charcoal heaters. Warmed to 65°. 2/	do.	do.
D	BRE 74450	CC	do.	Shipped cool; charcoal heaters. Held near 38°.	do.	do.
E	WFE 66444	(CW)-W	Moved to warm room at average temp. of 55-60° for 1 week before loading.	Shipped warm; charcoal heaters. Held near 65°.	do.	do.
F	WFE 67548	WW-B	Warmed 3 weeks in cellar from 43° to about 65°.	Shipped warm; charcoal heaters. Held near 65°.	Standard	C. Barbour
G	WFE 67887	WC-B	do.	Shipped cool; alcohol heaters set at 34°.	do.	do.
H	WFE 67189	CW-B	Kept cool until shipped.	Shipped warm; charcoal heaters. Warmed to 65°.	do.	do.
K	WFE 67523	CC-B	do.	Shipped cool; alcohol heaters set at 34°.	do.	do.

1/ W = warm; C = cold. The first letter indicates storage treatment; the second, shipping treatment. B indicates tests with second lot of potatoes.

2/ Gas samples for carbon dioxide determination.

Table 2. Plan of Experiment, Seed Potato Transportation Test, Gering, Nebraska to Robertsdale, Alabama - January 15 to 26, 1943.

TEST	CAR NO.	EXPERIMENT 1/	STORAGE TREATMENT	SHIPPING TREATMENT	CAR TYPE	GROWER
L	PFE 76430	WW-N	Prewarmed 18 days at 60-65° F.	Shipped warm; 2 alcohol heaters set at 55° F.	Preco Fans	H. Shaver
M	76464	WC-N	Prewarmed 18 days at 60-65°.	Shipped cool; 1 alcohol heater set at 34°	do	do
N	76191	CW-N	Kept cool until shipped.	Shipped warm; 2 alcohol heaters set at 60°. 2/	do	do
P	76198	CC-N	Kept cool until shipped.	Shipped cool; 1 alcohol heater set at 34°	do	do
R	76417	(CW)W-N	Prewarmed 1 week at 60-65°.	Shipped warm; 2 alcohol heaters set at 55°.	do	do
S	75869	WW-C	Prewarmed 3 weeks at 60-65°, then 5 weeks at 50-55°.	Shipped warm; 2 alcohol heaters set at 50°.	Standard	C. Barbour
T	75494	WC-C	Prewarmed 3 weeks at 60-65°, then 5 weeks at 50-55°.	Shipped cool; 1 alcohol heater set at 34°	do	do
V	75100	CW-C	Kept cool until shipped.	Shipped warm; 2 charcoal heaters. Raised to 65° aver. 2/	do	do
X	75396	CC-C	Kept cool until shipped.	Shipped cool; 2 charcoal heaters. Handled regular C. P. S.	do	do

1/ W = warm; C = cold. The first letter indicates storage treatment; the second, shipping treatment. The final letters (N or C) indicate tests with different lots of potatoes.

2/ Gas samples for carbon dioxide, oxygen, and carbon monoxide determination.

Pre-heating of Cars

Cars that were to be carried at the higher temperatures were pre-heated to some extent before loading. In the first test this was accomplished by lighting the charcoal heaters in the bunkers the evening before loading was begun. The heaters were removed from the bunkers a few minutes before the commencement of loading, and doors on both sides of the car were opened for a brief time to remove the fumes. This was not a very satisfactory procedure, as a brief airing did not clear fumes from the car; and with a longer airing much of the benefit from the pre-heating was lost.

For the second test some hot-blast kerosene heaters furnished by the Pacific Fruit Express Co. were used. These were placed in the body of the car and operated for a period of two to three hours prior to loading. A rapid increase in temperature was obtained, and no objectionable fumes were noted.

Method of Loading

All cars were loaded essentially by the "Pyramid Through Load" method, as developed and described by the Freight Container Bureau. 2/ In the first test a few slight variations occurred in loading due to unfamiliarity of some of the loaders with the method; but the variations were minor, and did not interfere with the proper carrying of the loads. All cars in the second test were loaded exactly according to the published description. A photograph of one of the partially completed loads in a test car is shown in Figure 1.

Placement of Thermometers

Potato temperatures were taken at ten different positions in each car by means of electrical resistance thermometers. As the danger of freezing damage is greatest in the layer next to the floor racks, thermometers were placed in potatoes in five bottom bags. Two thermometers were placed in potatoes in the center layer of bags and three in the top layer. Air temperatures were taken at the bottom bulkhead opening just below the floor rack, and at the top centerline doorway about 18 inches from the car ceiling. Detailed information on bulb placements is shown in Table 3.

2/ Recommended Arrangement for Loading 45,000 Pounds of Potatoes in 100-Pound Bags by the "Pyramid Through Load" Method. Bulletin No. 43, Association of American Railroads, Freight Container Bureau. December 1, 1942.

Table 3. Location of Electric Resistance Thermometers in Carloads of Seed Potatoes.

POSITION ON CABLE	TEMP. OF:	END OF CAR	LAYER	LOCATION / STACK	ROW
1	Air	East	Bottom 1/	Bunker	Centerline
2	Potato	East	Bottom 2/	Bunker	Centerline
3	Potato	East	Top 2/	Bunker	Centerline
4	Potato	East	Bottom 2/	Q-Length	Centerline
5	Potato	East	Middle 2/	Q-Length	Centerline
6	Potato	East	Top 2/	Q-Length	Centerline
7	Potato	Center	Bottom 2/	Doorway	North Side
8	Air	Center	Top 3/	Doorway	Centerline
9	Potato	West	Bottom 2/	Q-Length	Centerline
10	Potato	West	Middle 2/	Q-Length	Centerline
11	Potato	West	Top 2/	Q-Length	Centerline
12	Potato	West	Bottom 2/	Bunker	Centerline

1/ Bulb in front of bottom bulk-head opening, beneath floor rack.

2/ Bulb in potato about 12 in. down in sack from sewn end.

3/ Bulb hung from ceiling a few inches above top of load.

Gas Samples

Copper tubing of 1/4-inch outside diameter was placed in two cars in each test for the purpose of obtaining samples of the car atmosphere for analysis. One end of the tubing was placed about even with the top of the load at the doorway position and the other end was brought out between the doors and extended a few inches beyond the closed doors. Samples were obtained by drawing air through the tubing by means of an aspirator bulb. During the first test analyses were made at the time of sampling by means of a Hayes Portable Gas Analyzer. Due to the extremely slow absorption of oxygen, however, satisfactory analyses for oxygen and carbon monoxide could not be obtained by this method. During the second test samples were secured in gas sampling tubes, and these samples were analyzed for carbon dioxide, oxygen and carbon monoxide by means of an Orsat Gas Analyzer after the termination of the trip. All of the samples for gas analysis were drawn from the cars before the hatches were opened for the daily servicing of the heaters.

Test Bags for Planting Trials

Bags of the regular load in each car were specially marked with extra tags giving the car number and bag location and placed in each test car in the positions at which temperatures were taken. When cars of the first test were unloaded, one marked bag was withheld from each of three positions in each car representing the high, low and mean transit temperature. These bags were taken by representatives of the Texas Agricultural Experiment Substation at Weslaco for planting tests according to a prearranged plan. Marked bags from the cars in the second transportation test were taken from 2 bottom-layer, 2 middle-layer, and 2 top-layer positions in each car. These six bags from each car were delivered to representatives of the Alabama Gulf Coast Substation, Fairhope, for planting trials in Baldwin County to determine the time of emergence, growth, and yield when grown in replicated plots under comparable conditions.

RESULTS AND DISCUSSION

First Test - Nebraska to Texas

Loading

The nine cars involved in this test were loaded during a two-day period (December 14 and 15) in which outside temperatures ranged from 31° to 50° F. As shown in Table 1, temperatures of potatoes from the cellars varied from 42° to 48° at time of loading. The potatoes that had been pre-warmed at 60° - 65° for different periods before loading were hauled in open trucks for several miles to the cars, and cooled somewhat during that period. Most of the pre-warmed potatoes were 55° or warmer at loading, although a few temperatures lower than that were observed.

Table 4. Loading Data, Seed Potato Transportation Test - Nebraska 1942-1, Scottsbluff, Nebraska to Russelltown, Texas - December 1942.

	WFE 66486	WFE 66463	BRE 74445	BRE 74450	WFE 66444	WFE 67548	WFE 67887	WFE 67189	WFE 67523
Test designation	A	B	C	D	E	F	G	H	K
Experiment 1/	WW	WC	CW	CC	(CW)W	WW-B	WC-B	CW-B	CC-B
Resistance cable No.	418337	37469	23	30354	S-9	S-10	51	37470	25
Time loading started	Dec. 15 1:30 P	Dec. 15 10:00 A	Dec. 14 10:00 A	Dec. 14 4:00 P	Dec. 14 11:30 A	Dec. 14 9:25 A	Dec. 14 11:45 A	Dec. 14 3:00 P	Dec. 14 8:30 A
Time loading completed	Dec. 15 4:00 P	Dec. 15 2:30 P	Dec. 14 5:00 P	Dec. 15 10:20 A	Dec. 15 2:20 P	Dec. 14 2:00 P	Dec. 14 5:30 P	Dec. 15 11:55 A	Dec. 14 1:15 P
Air temp. in car at start, °F.	50°	43°	52°	52°	46°	52°	48°	52°	40°
Air temp. in car at finish, °F.	50°	52°	54°	---	---	56°	54°	48°	50°
Outside temp. during loading, °F.	46-48°	45-48°	40-45°	40-47°	41-46°	36-40°	42-45°	45-50°	31-40°
Number of 100-lb. sacks	450	450	450	450	450	450	450	450	450
Billed weight of load	45000	45000	45000	45000	45000	45000	45000	45000	45000
Method of loading	Pyramid	Pyramid	Pyramid	Pyramid	Pyramid	Pyramid	Pyramid	Pyramid	Pyramid
Temp. of potatoes at loading-range	55-59°	52-59°	44-47°	44-46°	55-64°	44-56°	54-65°	44-46°	42-48°
Temp. of potatoes at loading-aver.	57°	55.5°	45°	45°	59°	51°	58°	45°	45.5°

1/ See footnote 1, Table 1.

Schedule and Outside Temperatures

Loading was completed at 4:00 P.M. on December 15, and the test cars left Scottsbluff at 10:15 P.M. The route and schedule of the test train between Scottsbluff, Nebraska, and Russelltown, Texas, are shown in Table 5.

Outside temperatures throughout the trip were moderate to warm (Figure 2). As a result, the trip was not as productive of results on efficiency of heater operation as it would have been had lower temperatures prevailed.

Heater Operation

The record of heater manipulation is shown in Tables 6, 7, and 8. Difficulty was encountered when the fire in charcoal heaters would get up into the magazine. There is some evidence that this was due to the increased draught from fan operation. The evidence, however, is not conclusive, for the rear heater in Car H (Standard Car) and the front heater in Car A burned in the magazine, each at a time when the front fan was turned off. Some trouble was also caused by the heaters' going out even though there was abundant fuel present in the magazines. It was felt, however, that this was due to the use of the large size charquettes. These were not recommended for the smaller heaters, but were used because none of the small size charquettes were available.

Unfortunately, no information was secured on the operation of the F.G.E. automatic heaters. The thermostats on these were set at 32°, and because of the moderate weather encountered enroute, the air temperature in the cars containing the automatic heaters never reached a temperature sufficiently low to start the heaters.

Circulating Fans

Air temperatures taken at the top doorway and bottom bulkhead positions in Cars C and H are shown in Figure 2. These curves illustrate very clearly the effectiveness of the circulating fans in equalizing temperatures throughout the car. Car H (Standard Car) shows a rapid spread in air temperature after the heaters were lighted on December 15. The charcoal heaters in this car were both operating with the draft slides set at "fast burn" until noon of December 18. At that time there was a spread of 23 degrees F. between air temperatures in the two positions. The draft slides were then adjusted to "slow burn" and as a result, the top air temperature was gradually decreased. The bottom air temperature rose gradually throughout the trip, partly at least, as a result of moderate outside temperatures. Car C was loaded on December 14 and the heaters lighted the same afternoon. There was a sharp rise in top air temperature while the car was standing; but this was decreased appreciably after it started moving. The spread between top and bottom air temperatures was only from 5 to 8 degrees after the trip was begun. Potato temperatures were also equalized materially by the fans. This was particularly noticeable in the cars which were loaded with cool potatoes and warmed in transit. The potatoes in Car C (Figure 5) showed a temperature spread of only 2 to 4 degrees after the cars started moving; whereas the

Table 5. Schedule of Test Train - Scottsbluff, Nebraska to Russelltown, Texas - Routing, C. B. & Q., Scottsbluff to Kansas City: M. P., Kansas City to Russelltown, Texas - Transportation Test, Nebraska, 1942-1.

ARRIVED		STATION	DEPARTED	
DATE	TIME		DATE	TIME
		Scottsbluff, Nebr.	12-15	10:15 P.M.
12-16	2:30 A.M.	Alliance, Nebr.	12-16	4:05 A.M.
12-16	7:30 A.M. (MT)	Seneca, Nebr.	12-16	8:05 A.M.
12-16	1:10 P.M. (CT)	Ravenna, Nebr.	12-16	1:50 P.M.
12-16	6:15 P.M.	Lincoln, Nebr.	12-16	10:00 P.M.
12-17	6:30 A.M.	Kansas City, Mo.	12-17	1:10 P.M.
12-17	6:30 P.M.	Sheldon, Mo.	12-17	7:00 P.M.
12-18	7:15 A.M.	Cotter, Ark.	12-18	8:15 A.M.
12-18	11:25 A.M.	Wynne, Ark.	12-18	12:20 P.M.
12-18	9:55 P.M.	McGehee, Ark.	12-19	8:50 A.M.
12-19	9:00 P.M.	Alexandria, La.	12-20	12:50 A.M.
12-20	5:00 A.M.	DeQuincy, La.	12-20	7:30 A.M.
12-20	4:10 P.M.	Houston, Texas	12-20	6:45 P.M.
12-21	4:00 A.M.	Kingsville, Texas	12-21	5:00 A.M.
12-21	9:00 A.M.	Harlingen, Texas	12-21	10:30 A.M.
12-21	1:30 P.M.	Russelltown, Texas		

Table 6. Record of Heater and Fan Operation - Seed Potato Transportation Test - Nebraska, 1942-1 - Scottsbluff, Nebraska to Russelltown, Texas - December 1942.

STATION	DATE	TIME	WFE 66486 - CAR A				WFE 66463 - CAR B				BRE 74445 - CAR C			
			FRONT		REAR		FRONT		REAR		FRONT		REAR	
			HEATER	FAN	HEATER	FAN	HEATER	FAN	HEATER	FAN	HEATER	FAN	HEATER	FAN
Scottsbluff, Nebr.	Dec. 13	10:00P	Fast burn	off	Dark	off	Dark	off	Dark	off	Fast burn	off	Dark	off
Do.	Dec. 14	9:00A	Pulled 1/	do.	do.	do.	do.	do.	do.	do.	Pulled	do.	do.	do.
Do.	do.	6:00P	Fast burn	do.	do.	do.	do.	do.	do.	do.	Fast burn	do.	do.	do.
Do.	Dec. 15	9:00A	Pulled	do.	do.	do.	do.	do.	do.	do.	Pulled	do.	do.	do.
Do.	do.	3:30P	Slow burn	on	Slow burn	on	do.	on	do.	on	Slow burn	on	Slow burn	on
Ravenna, Nebr.	Dec. 16	1:20P	do.	do.	do.	do.	do.	do.	do.	do.	do.	do.	do.	do.
Lincoln, Nebr.	do.	6:45P	Fast burn	do.	Fast burn	do.	do.	do.	do.	do.	Fast burn	do.	Fast burn	do.
Sheldon, Mo.	Dec. 17	6:45P	do.	do.	Fire in magazine; slow burn	do.	do.	do.	do.	do.	Fire in magazine; slow burn	do.	do.	do.
Wynne, Ark.	Dec. 18	12:05P	do. 2/	off	Darkened	do.	do.	do.	do.	do.	Slow burn 2/	do.	do.	do.
McGehee, Ark.	do.	10:00P	do. 2/	do.	do.	do.	do.	do.	do.	do.	do.	do.	do.	do.
Do.	Dec. 19	8:00A	Fire in magazine; med. burn	do.	do.	do.	do.	do.	do.	do.	do.	do.	Slow burn	do.
Collinston, La.	do.	1:00P	Med. burn	do.	do.	do.	do.	do.	do.	do.	do.	do.	do.	do.
Alexandria, La.	do.	9:30P	do.	do.	do.	do.	do.	do.	do.	do.	do.	do.	do.	do.
Elizabeth, Tex.	Dec. 20	12:30P	Darkened	do.	do.	do.	do.	do.	do.	do.	do.	do.	Darkened	do.
Houston, Tex.	do.	4:30P	do.	on	do.	do.	do.	do.	do.	do.	Darkened at 5:30P	do.	do.	do.

1/ Refers to opening of draught slide on side of heater.

2/ Fire out, relighted.

Table 7. Record of Heater and Fan Operation - Seed Potato Transportation Test - Nebraska, 1942-1 - Scottsbluff, Nebraska to Russelltown, Texas - December 1942.

STATION	DATE	TIME	BRE 74450 - CAR D				WFE 66444 - CAR E				WFE 67548 - CAR F	
			FRONT		REAR		FRONT		REAR		FRONT	REAR
			HEATER	FAN	HEATER	FAN	HEATER	FAN	HEATER	FAN	HEATER	HEATER
Scottsbluff, Nebr.	Dec. 13	10:00P	Dark	off	Dark	off	Fast burn	off	Dark	off	Fast burn	Dark
Do.	Dec. 14	9:00A	do.	do.	do.	do.	Pulled 1/	do.	do.	do.	Pulled	do.
Do.	do.	6:00P	do.	do.	do.	do.	do.	do.	do.	do.	Fast burn	do.
Do.	Dec. 15	9:00A	do.	do.	do.	do.	do.	do.	do.	do.	do.	Fast burn
Do.	do.	3:30P	do.	on	do.	on	Slow burn	on	Slow burn	on	do.	do.
Ravenna, Nebr.	Dec. 16	1:20P	do.	do.	do.	do.	do.	do.	do.	do.	Slow burn	Darkened
Lincoln, Nebr.	do.	6:45P	do.	do.	do.	do.	Fast burn	do.	Fast burn	do.	do.	do.
Sheldon, Mo.	Dec. 17	6:45P	do.	do.	do.	do.	do.	do.	Fire in magazine; slow burn	do.	do.	do.
Wynne, Ark.	Dec. 18	12:05P	do.	do.	do.	do.	do.	off	Darkened	do.	do.	do.
McGehee, Ark.	do.	10:00P	do.	do.	do.	do.	do.	do.	do.	do.	do.	do.
Do.	Dec. 19	8:00A	do.	do.	do.	do.	do.	do.	do.	do.	do.	do.
Collinston, La.	do.	1:00P	do.	do.	do.	do.	do.	do.	do.	do.	do.	do.
Alexandria, La.	do.	9:30P	do.	do.	do.	do.	do.	do.	do.	do.	do.	do.
Elizabeth, Tex.	Dec. 20	12:30P	do.	do.	do.	do.	Darkened	do.	do.	do.	do.	do.
Houston, Tex.	do.	4:30P	do.	do.	do.	do.	do.	on	do.	do.	Fire out; left dark	do.

1/ Refers to opening of draught slide on side of heater.

Table 8. Record of Heater and Fan Operation - Seed Potato Transportation Test - Nebraska, 1942-1 - Scottsbluff, Nebraska to Russelltown, Texas - December 1942

STATION	DATE	TIME	WFE 67887 - CAR G		WFE 67189 - CAR H		WFE 67523 - CAR K	
			FRONT HEATER	REAR HEATER	FRONT HEATER	REAR HEATER	FRONT HEATER	REAR HEATER
Scottsbluff, Nebr.	Dec. 13	10:00P	Dark	Dark	Fast burn	Dark	Dark	Dark
Do.	Dec. 14	9:00A	do.	do.	Pulled 1/	do.	do.	do.
Do.	do.	6:00P	do.	do.	Fast burn	do.	do.	do.
Do.	Dec. 15	9:00A	do.	do.	Pulled	do.	do.	do.
Do.	do.	3:30P	Set at 32°	Set at 32°	Fast burn	Fast burn	Set at 32°	Set at 32°
Ravenna, Nebr.	Dec. 16	1:20P	do.	do.	do.	do.	do.	do.
Lincoln, Nebr.	do.	6:45P	do.	do.	do.	do.	do.	do.
Sheldon, Mo.	Dec. 17	6:45P	do.	do.	do.	do.	do.	do.
Wynne, Ark.	Dec. 18	12:05P	do.	do.	Slow burn	Slow burn	do.	do.
McGehee, Ark.	do.	10:00P	do.	do.	do.	do.	do.	do.
Do.	Dec. 19	8:00A	do.	do.	do.	do.	do.	do.
Collinston, La.	do.	1:00P	do.	do.	Slow burn 2/	Fire in magazine; darkened	do.	do.
Alexandria, La.	do.	9:30P	do.	do.	Darkened	Dark	do.	do.
Elizabeth, Tex.	Dec. 20	12:30P	do.	do.	do.	do.	do.	do.
Houston, Tex.	do.	4:30P	do.	do.	do.	do.	do.	do.

1/ Refers to opening of draught slide on side of heater
2/ Fire out, relighted.

potatoes in Car H (Figure 10) increased in temperature spread for several days, and on December 18 there was 18 degrees difference between average potato temperatures in the top and bottom layers. All five of the cars containing circulating fans showed very uniform potato temperatures throughout the trip.

Potato Temperatures

Car A - Figure 3.

This car was loaded with potatoes that had been pre-warmed for four weeks and were to be carried at an average temperature of about 65°. As shown in Figure 3, the potatoes were 55° to 56° at loading and gradually increased in temperature throughout the transit period. They reached an average temperature of 65° on December 19 and were 68° to 69° when unloaded. Even temperatures were maintained by the operation of the built-in circulating fans.

Car B - Figure 4.

The potatoes loaded in this car were pre-warmed for four weeks and were to be cooled in transit. Outside temperatures were not conducive to cooling the load with the result that the potatoes cooled a few degrees during the first day in transit, and then remained slightly under 55° through December 19, after which they gradually warmed to an average of about 58° at unloading. Heaters were not lighted in this car and the ventilators were closed throughout the trip.

Car C - Figure 5.

This car was loaded with potatoes from a cool cellar. These were to be warmed to 65° in transit for the purpose of determining whether the desired effect upon the seed potatoes could be secured by a short warming period while the potatoes were in transit. At the completion of loading, potato temperature averaged 41°. The potatoes were gradually warmed by means of charcoal heaters, but their temperature did not reach an average of 65° until the afternoon of December 20. At unloading time the potato temperature averaged about 69°. The warming of the load to 65° was somewhat slower than was desired for the purposes of the experiment; but it must be kept in mind that the charcoal heaters in use were developed for protection of the load against freezing and are of limited heating capacity. Calculation of the amount of heat required to raise 45,000 pounds of potatoes from 41° to 65° F. shows the following: 45,000 x .8 x 24 = 864,000 B.t.u. The commonly used charcoal heater burns approximately 1/2 pound of charcoal an hour with the draft slide open, which means that approximately 1 pound of charcoal is burned per hour in two heaters. Charcoal produces approximately 13,000 B.t.u. per pound when burned; so theoretically, it would require 864,000 ÷ 13,000 or about 66-1/2 hours to raise 45,000 pounds of potatoes from 41° to 65° by means of two charcoal heaters. This calculation does not take into consideration warming the containers, heat transfer through the car walls, or the heat of respiration. That a period of about 140 hours was actually required to raise the average temperature to 65° is perhaps due to the fact that heaters were operating

on slow-burn draft adjustment during part of this period in an effort to prevent fires in the magazines; and also due to the fact that one heater went out sometime between December 17 and 18, and was relighted about noon on December 18.

Car D - Figure 6.

These potatoes were loaded into the car from cool storage and were transported cool. As shown in the curves, these potatoes carried at temperatures below 45° for about 4 days, and then gradually rose in temperature to 51° to 54° at time of unloading. No heaters were operated in this car and the ventilators were closed throughout the trip.

Car E - Figure 7.

This car was loaded with potatoes that had been pre-warmed for 1 week and were loaded at temperatures from 53° to 54°. Temperatures throughout the load were raised gradually by means of charcoal heaters, so that the load averaged 65° by the afternoon of December 19. At unloading, potato temperatures were from 68° to 70°.

Car F - Figure 8.

This standard car without fans was loaded with potatoes that had been pre-warmed for 3 weeks. Potatoes in the top layer rose rapidly in temperature, reaching 65° by the afternoon of December 16. The middle layer of potatoes increased in temperature more gradually, reaching 60° at noon on December 18 and 65° only at the end of the trip. The average temperature in the bottom-layer potatoes did not reach 60° until December 20, and never did rise to 65°.

Car G - Figure 9.

This also was a standard car and was loaded with potatoes that had been pre-warmed for 3 weeks. The potatoes averaged about 54° to 55° at loading, and those in the top and middle layers rose very gradually to about 57° on the sixth day. The top layer of potatoes then rose more rapidly to a temperature of 64° at unloading. Potatoes in the bottom layer decreased slightly in temperature for the first 2 days, and then rose slowly to about 58° at unloading. Ventilators were closed during the entire trip; and the automatic heaters did not turn on, due to the air temperature being continuously above the thermostat setting.

Car H - Figure 10.

Potatoes were loaded into this car from a cool cellar, but were at temperatures of nearly 49° when loading was completed. The load was warmed in transit by means of 2 charcoal heaters. As the car was not equipped with fans, the spread in potato temperature was increasingly great for several days after departure. Potatoes in the top layer reached 65° by the evening of December 17; while those in the bottom layer reached 65° only on the last day just prior to unloading. There was a spread of about 17° between top-layer and bottom-layer potato temperatures on December 18.

Car K - Figure 11.

This also was a standard car, was loaded with potatoes from a cool cellar, and was shipped with automatic heaters set at 32°. Potato temperatures remained fairly even throughout the load for the first four days, gradually rising from 43°—44° to 46°—47°. The top-layer potatoes then rose more rapidly, due to higher outside temperatures, and averaged about 59° at unloading. Potatoes in the bottom layer averaged about 52° at unloading, and those in the middle layer about 54°.

Carbon Dioxide

The concentrations of carbon dioxide found in Cars H and C at top of load level are shown in Table 9. Loading on Car H was completed at noon on December 15, and the charcoal heaters were placed in the bunkers at 3:30 P.M. As Car H did not have circulating fans, there is some possibility that CO_2 concentration might have been somewhat higher near the floor of the car from which no samples could be taken. In this car there was a gradual increase in carbon dioxide concentration, from 1 percent on the afternoon of December 16 to 3.2 percent on the afternoon of december 19. On December 20, after both heaters had been darkened for 18 hours, the concentration dropped to 1/2 percent.

Car C, which was equipped with circulating fans, was loaded on December 14, and the two charcoal heaters burned all through the night of December 14. They were removed for a few hours on December 15, and replaced in the bunkers at 3:30 P.M. Thus Car C had had about 15 hours more heating than Car H at the time the first gas sample was taken. In addition the air in Car C had been well stirred by 15 hours of fan operation preceding the taking of the first sample. As shown in the table, 4.8 percent of carbon dioxide was found in Car C at the first sampling on December 16. Subsequent readings showed 3.2 and 4.0 percent CO_2 when 2 heaters were operating, and 1.6 to 2.2 percent CO_2 with only one heater burning.

Condition at Unloading

The loads were in very good condition when the doors were opened at destination. Very few bags were in contact with the side walls, and little shifting had occurred. There was moderate bruising and friction injury on the potatoes adjacent to the floor racks, which was expected as no paper or padding was used on the floor racks. However, no injury was present which would detract from their value as seed. Examination of the potatoes showed no evidence of sprout growth on any of the potatoes; and in a subsequent cutting of a number of potatoes from each car, no sign of blackheart was seen. Apparently the heating of the cars was not sufficiently rapid to induce blackheart which has been reported by other workers as associated with oxygen deficiency resulting from a rapid increase in respiration rate with a rise in temperature.

Table 9. Carbon Dioxide Concentrations in Heated Cars of Seed Potatoes - Scottsbluff, Nebraska to Russelltown, Texas - Transportation Test - Nebraska, 1942-1.

DATE	TIME	WFE 67189 - CAR H		BRE 74445 - CAR C	
		CARBON DIOXIDE	OPERATION OF HEATERS	CARBON DIOXIDE	OPERATION OF HEATERS
		Percent		Percent	
Dec. 16	1:20 P.M.	1.0	Two heaters on; fast burn 1/	4.8	Two heaters on; slow burn 1/
Dec. 17	6:00 P.M.	2.6	Two heaters on; fast burn	3.2	Two heaters on; fast burn
Dec. 18	5:00 P.M.	3.0	Two heaters on; slow burn	1.6	One heater on; fast burn
Dec. 19	5:00 P.M.	3.2	One heater on; slow burn	4.0	Two heaters on; slow burn
Dec. 20	4:30 P.M.	0.5	Both heaters darkened for 18 hours.	2.2	One heater on; slow burn

1/ Simplex charcoal heaters

Second Test - Nebraska to Alabama

Loading

The nine cars, constituting the second test, were loaded at Gering, Nebraska on January 15, 16, and 17. During the first day of loading the outside temperature ranged from 40° to 58°, but during the night of January 15-16 the temperature dropped sharply with the result that loading was restricted during the next 2 days to a few hours during mid-day when temperatures were above zero. As the potatoes were hauled several miles to the cars, special precautions were used to prevent freezing on the trucks. Canvases, covering the entire load, were used on the trucks and were unrolled over the bags as they were loaded and rolled back in unloading. As additional protection, a layer of several inches of shredded paper was used on the truck floors. Numerous checks were made on potato temperatures during the time they were loaded into the cars to determine that no freezing had occurred. Car doors were closed except when actual loading was in progress, and heaters were operated in the cars as soon as any potatoes were placed in them. Potato temperatures at loading, the time of loading, and other pertinent data are shown in Table 10.

Schedule and Outside Temperatures

The test cars left Gering in the afternoon of January 17. The detailed schedule of the test train is shown in Table 11. As will be noted, the test cars remained in Council Bluffs, Iowa for about 26 hours, due to traffic difficulties caused by drifting snow and severe cold.

A record of outside temperatures during the loading and transit period is shown in Figure 12. Outside temperatures during the first 3 days of the test were mainly below zero with a low reading of -16° F. at Grand Island, Nebraska. During January 21 and 22 the temperature rose steadily, reaching almost 80° on the afternoon of January 22. On the following days the temperature remained warm, being above 60° a major part of the time.

Heater Operation

All of the fan cars and two of the standard cars were equipped with thermostatically controlled alcohol heaters. The heaters in the cars to be shipped warm at first were set at 65°, but it was determined during loading that the setting was too high, since the heater is placed near the floor and the temperatures at the thermostat are much lower than those prevailing nearer the car ceiling. Accordingly, the thermostats were set at 50° while the cars were standing during loading, and were adjusted to a final setting just before the cars left Gering. Detailed data on heater and fan operation are shown in Tables 12 and 13. The ventilator manipulation, and the lighting and darkening of the charcoal heaters are shown in Table 14.

A thermostat setting of 55° appeared to be about correct for maintaining a warm load at temperatures around 65° in a fan car. At this setting the heaters were burning a sufficient proportion of the time to raise the average load temperature gradually from 60° to 68° in about 10 days.

Table 10. Loading Data - Seed Potato Transportation Test - Nebraska, 1943-1 - Gering, Nebraska to Robertsdale, Alabama - January 1943.

	PFE 76430	PFE 76464	PFE 76191	PFE 76198	PFE 76417	PFE 75869	PFE 75494	PFE 75100	PFE 75396
Test designation	L	M	N	P	R	S	T	V	X
Experiment 1/	WW-N	WC-N	CW-N	CC-N	(CW)W-N	WW-C	WC-C	CW-C	CC-C
Resistance cable No.	30354	52	60	48	23	S-9	25	47	37469
Time loading started	Jan. 15 10:45A	Jan. 15 2:30P	Jan. 16 2:15P	Jan. 16 3:30P	Jan. 15 10:20A	Jan. 15 1:40P	Jan. 15 5:00P	Jan. 15 10:30A	Jan. 16 5:15P
Time loading completed	Jan. 15 6:00P	Jan. 15 4:45P	Jan. 16 3:45P	Jan. 17 1:30P	Jan. 15 2:15P	Jan. 15 4:45P	Jan. 16 4:30P	Jan. 15 3:30P	Jan. 17 1:30P
Air temp. in car at start, °F.	58°	53°	45°	45°	67°	51°	49°	56°	45°
Air temp. in car at finish, °F.	46°	49°	41°	43°	50°	55°	---	53°	42°
Outside temp. during loading, °F.	58-40°	57-43°	7°	2°	50°	52°	43-0°	50°	2°
Number of 100-lb. sacks	450	450	450	450	450	450	450	450	450
Billed weight of load	45000	45000	45000	45000	45000	45000	45000	45000	45000
Method of loading	Pyramid	Pyramid	Pyramid	Pyramid	Pyramid	Pyramid	Pyramid	Pyramid	Pyramid
Temp. of potatoes at loading-range	54-61°	56-64°	39-44°	33-43°	54-63°	48-50°	38-47°	43-46°	36-42°
Temp. of potatoes at loading-aver.	58°	60°	42°	39°	59°	49°	43°	44°	39°

1/ See footnote 1, Table 2.

Table 11. Schedule of Test Train - Gering, Nebraska to Robertsdalle, Alabama - Routing: U.P., Gering to Council Bluffs; I.C., Council Bluffs to Gulfport; L & N, Gulfport to Robertsdale - Transportation Test - Nebraska, 1943-1.

ARRIVAL		STATION	DEPARTURE	
DATE	TIME		DATE	TIME
		Gering, Nebraska	1/17	3:20P
1/17	5:30P	Lewellen, Nebraska	do.	6:00P
Do.	8:45P MT	North Platte, Neb.	1/18	2:05A CT
1/18	8:10A	Grand Island, Neb.	do.	10:10A
Do.	4:55P	Council Bluffs, Io.	1/19	7:00P
1/20	5:25A	Waterloo, Io.	1/20	6:35A
Do.	1:10P	Freeport, Ill.	do.	1:25P
Do.	5:30P	Hawthorne, Ill.(Chicago)	1/21	6:30A
1/21	11:10A	Champaign, Ill.	do.	12:55P
Do.	6:10P	Bluford, Ill.	do.	8:05P
1/22	2:50A	Fulton, Ky.	1/22	4:00A
Do.	9:30A	Memphis, Tenn.	do.	11:00A
Do.	7:10P	Gwin, Miss.	do.	7:50P
Do.	11:55P	Jackson, Miss.	1/23	2:00A
1/23	10:30A	Gulfport, Miss.	1/23	4:20P
Do.	11:40P	Mobile, Ala.	1/25	7:00A
1/25	12:30P	Bay Minette, Ala.	do.	8:00P
Do.	10:30P	Robertsdale, Ala.		

Table 12. Record of Heater, Fan, and Ventilator Operation - Seed Potato Transportation Test - Nebraska, 1943-1 - Gering, Nebraska to Robertsdale, Alabama - January 1943.

STATION	DATE	TIME	PFE 76430 - CAR L				PFE 76464 - CAR M				PFE 76191 - CAR N			
			FRONT ALCOHOL HEATER	FAN	REAR ALCOHOL HEATER	FAN	FRONT ALCOHOL HEATER	FAN	REAR ALCOHOL HEATER	FAN	FRONT ALCOHOL HEATER	FAN	REAR ALCOHOL HEATER	FAN
Gering, Nebraska	Jan. 15	5:30P	Dark	off	Dark	off	Set at 34°	off	-----	off	Dark	off	Dark	off
Gering, Nebraska	Jan. 15	6:00P	On-set at 65°	off	On-set at 65°	off	Set 34°	off	-----	off	Dark	off	Dark	off
Gering, Nebraska	Jan. 16	9:40P	Set 50°	off	Set 50°	off	Set 34°	off	-----	off	On-set at 50°	off	On-set at 50°	off
Gering, Nebraska	Jan. 16	3:15P	Set 50°	off	Set 50°	off	Set 34°	off	-----	off	On-set at 50°	off	On-set at 50°	off
Gering, Nebraska	Jan. 17	2:30P	Set 55°	on	Set 55°	on	Set 34°	off	------	on	Set 60°	on	Set 60°	on
Chicago, Illinois	Jan. 20	6:00P	Set 55°	on	Set 55°	on	Set 34°	off	-----	on	Set 60°	on	Set 60°	on
Effingham, Ill.	Jan. 21	3:30P	Set 55°	on	Set 55°	on	Set 34°	off	-----	on	Set 60°	on	Set 60°	on
Memphis, Tenn.	Jan. 22	10:00A	Set 55°	on	Set 55°	on	Darkened	on	-----	on	Set 60°	on	Set 60°	on
Jackson, Miss.	Jan. 22	11:50P	Darkened	on	Darkened	on	Darkened	on	-----	on	Set 60°	on	Set 60°	on
Gulfport, Miss.	Jan. 23	11:00A	Pulled	on	Pulled	on	Pulled	on	-----	on	Pulled	on	Pulled	on
*Robertsdale, Ala.	Jan. 25	10:30P	------	on	------	on	------	on	-----	on	-----	on	-----	on

* Through a misunderstanding the ventilators were opened on all cars sometime during the night of Jan. 24. They were closed at Bay Minette at noon on January 25.

Table 13. Record of Heater, Fan, and Ventilator Operation - Seed Potato Transportation Test - Nebraska, 1943-1 - Gering, Nebraska to Robertsdale, Alabama - January 1943.

STATION	DATE	TIME	PFE 76198 - CAR P				PFE 76417 - CAR R				PFE 75869 - CAR S			
			FRONT ALCOHOL HEATER	FAN	REAR ALCOHOL HEATER	FAN	FRONT ALCOHOL HEATER	FAN	REAR ALCOHOL HEATER	FAN	FRONT ALCOHOL HEATER	VENT.	REAR ALCOHOL HEATER	VENT.
Gering, Nebraska	Jan. 15	5:00P	-------	---	-----	---	On-set at 65°	off	On-set at 65°	off	On-set at 60°	Closed	On-set at 60°	Closed
Gering, Nebraska	Jan. 16	9:30A	-------	---	-----	---	Set 50°	off	Set 50°	off	Set 50°	Closed	Set 50°	Closed
Gering, Nebraska	Jan. 16	3:30P	On-set-at 50°	off	-----	off	Set 50°	off	Set 50°	off	Set 50°	Closed	Set 50°	Closed
Gering, Nebraska	Jan. 16	4:00P	Set 34°	off	------	off	Set 50°	off	Set 50°	off	Set 50°	Closed	Set 50°	Closed
Gering, Nebraska	Jan. 17	2:30P	Set 34°	off	-----	on	Set 55°	on	Set 55°	on	Set 50°	Closed	Set 50°	Closed
Council Bluffs, Io.	Jan. 19	10:30P	Set 34°	off	-----	on	Set 55°	on	Set 55°	on	Turned off	Closed	Set 50°	Closed
Chicago, Ill.	Jan. 20	5:00P	Set 34°	Turned on	-----	on	Set 55°	on	Set 55°	on	Dark	Closed	Set 50°	Closed
Kankakee, Ill.	Jan. 21	8:30A	Set up to 40° at 11:00A	on	-----	on	Set 55°	on	Set 55°	on	Dark	Closed	Set 50°	Closed
Effingham, Ill.	Jan. 21	3:30P	Re-set at 34°	on	-----	on	Set 55°	on	Set 55°	on	Dark	Closed	Set 50°	Closed
Memphis, Tenn.	Jan. 22	10:00A	Darkened	on	-----	on	Set 55°	on	Set 55°	on	Dark	Closed	Set 50°	Closed
Gulfport, Miss.	Jan. 23	11:00A	Pulled	on	-----	on	Pulled	on	Pulled	on	Pulled	Closed	Pulled	Closed
*Robertsdale, Ala.	Jan. 25	10:30P	-------	on	-----	on	-----	on	-----	on	-----	Closed	-----	Closed

*Through a misunderstanding the ventilators were opened on all cars sometime during the night of January 24. They were closed at Bay Minette at noon on January 25.

Table 14. Heater and Ventilator Operation - Seed Potato Transportation Test - Nebraska, 1943-1 - Gering, Nebraska to Robertsdale, Alabama - January 1943.

STATION	DATE	TIME	PFE 75494 - CAR T				PFE 75100 - CAR V				PFE 75396 - CAR X			
			FRONT ALCOHOL HEATER	VENT.	REAR ALCOHOL HEATER	VENT.	FRONT CHARCOAL HEATER	VENT.	REAR CHARCOAL HEATER	VENT.	FRONT CHARCOAL HEATER	VENT.	REAR CHARCOAL HEATER	VENT.
Gering, Nebraska	Jan. 15	4:30P	------	----	------	----	Lighted	Closed	Lighted	Closed	------	----	------	----
Gering, Nebraska	Jan. 16	4:30P	Set 34°	Closed	----	Closed	on	Closed	on	Closed	Lighted	Closed	Lighted	Closed
Gering, Nebraska	Jan. 17	2:30P	Set 34°	Closed	----	Closed	on	Closed	on	Closed	on	Closed	Darkened at 1:00P	Closed
North Platte, Nebr.	Jan. 17	10:30P	Set 34°	Closed	----	Closed	on	Closed	on	Closed	on	Closed	Re-Lighted	Closed
Council Bluffs, Io.	Jan. 19	10:30A	Set 34°	Closed	----	Closed	on	Closed	on	Closed	on	Closed	on	Closed
Council Bluffs, Io.	Jan. 19	2:15P	Set 34°	Closed	----	Closed	on	Closed	on	Closed	on	Closed	Darkened at 2:15P	Closed
Chicago, Ill.	Jan. 20	6:00P	Set 34°	Closed	----	Closed	on	Closed	Darkened at 5:00P	Closed	on	Closed	Dark	Closed
Kankakee, Ill.	Jan. 21	8:30A	Set 34°	Closed	----	Closed	on	Closed	Dark	Closed	Darkened	Closed	Dark	Closed
Effingham, Ill.	Jan. 21	3:30P	Set 34°	Closed	----	Closed	on	Closed	Dark	Closed	Darkened	Open	Dark	Open
Memphis, Tenn.	Jan. 22	10:00A	Darkened	Closed	----	Closed	on	Closed	Dark	Closed	Darkened	Open	Dark	Open
Gulfport, Miss.	Jan. 23	11:00A	Pulled	Closed	----	Closed	Pulled	Closed	Pulled	Closed	Pulled	Open	Pulled	Open
*Robertsdale, Ala.	Jan. 25	10:30P	------	Closed	----	Closed	-----	Closed	------	Closed	------	Open	------	Open

* Through a misunderstanding the ventilators were opened on all cars sometime during the night of January 24. They were closed in all but the C.P.S. car (X) at Bay Minette at noon on January 25.

Car N, the fan car that was loaded with cool potatoes to be warmed in transit, had the alcohol heaters set at 60° as a greater amount of heat was required in this car. Cars to be transported at lower temperatures were equipped with only one alcohol heater, which was placed in the front bunker with the thermostat set at 34°. Car S (Standard Car) originally had one alcohol heater operating in each bunker with the thermostat set at 50°; but the front heater was turned off in Council Bluffs because of excessive temperatures in the top of the load. Without fans to circulate the air, the two heaters burned continuously at a setting of 50°.

Car X, a standard car with charcoal heaters, was operated under the regular Carriers' Protective Service rules, namely: front heater, lighted at an outside temperature of 20°; rear heater, lighted at -5°; heaters darkened in the same order, and ventilators opened at 32°.

Fuel consumption in the automatic alcohol heaters is shown in Table 15.

Circulating Fans

As shown in Tables 12 and 13, fan cars with a heater only in the front end had only the rear fan turned on. This was done to prevent the warm air from circulating in only one end of the car with the attendant danger of freezing temperatures in the end without a heater. Car P was operated with one heater set at 34°, and the fan operating in the opposite end of the car from Gering to Chicago. At this point the potato temperature in the bottom bunker position at the front end had dropped to 33°; and, as the outside temperature was low, the heater was set up to 40° temporarily and the front fan turned on. The temperatures, resulting from these manipulations, make an interesting study in air movements. A graphic portrayal of the potato temperatures after loading, with only the rear fan operating as well as with both fans operating, is shown in Figure 13. It appears from the temperature distribution that warm air from the heater moved by natural convection through the top bulkhead opening, and there met the stream of air driven along the top of the load by the operation of the fan at the rear. The warm air was drawn into the stream and passed back through the load along the sides of the car to the fan, as shown by the arrows in the diagram. Air return through the bottom bulkhead opening of the front bunker was only that caused by natural convection; and it was rather slow, as indicated by the potato temperature of 33° at the bottom bunker and the air temperature of 27.5° secured just before turning on the second fan.

The lower figure shows the potato temperatures at the first reading, made after turning on the front fan. It will be noted that the front top temperature dropped several degrees, and that at the front bottom bunker position rose 1-1/2 degrees. The bottom air temperature rose 6-1/2 degrees to 34°. Temperatures in the rear half of the car all dropped slightly as heat from the front heater was now circulated principally in the front half of the car.

Table 15. Record of Alcohol-Supplied Heaters - Seed Potato Transportation Test - Nebraska, 1943-1 - Gering, Nebraska to Robertsdale, Alabama - January 1943.

STATION	DATE	PFE 76430		PFE 76464		PFE 76191		PFE 76198		PFE 76417		PFE 75869		PFE 75494	
		HEAD	REAR	HEAD	REAR	HEAD	REAR	HEAD	REAR	HEAD	REAR	HEAD	REAR	HEAD	REAR
		Gals.	Gals.	Gals.	Gals.	Gals.	Gals.	Gals.	Gals.	Gals.	Gals.	Gals.	Gals.	Gals.	Gals.
Gering, Nebr.	1/15	5	5	5	0	5	5	5	0	5	5	5	5	5	0
Gering, Nebr.	1/17	2	2								2	1-1/2		2	
North Platte, Nebr.	1/17	2	2			2	2			2	2	4-3/4		2	
Council Bluffs, Io.	1/18	2-1/8	2-7/8	2-1/4		2-1/8	3-3/8	3-1/2		1-1/2	2	3-1/8	4-1/8	3-1/8	
Waterloo, Io.	1/20			2-3/8											
Freeport, Ill.	1/20					2-5/8	2-3/8								
Chicago, Ill.	1/20	2-1/2								2	2-7/8		3	2-1/8	
Bluford, Ill.	1/21		1-1/8			2-1/2							1-1/4		
Total gal. supplied		13-5/8	13	9-5/8		14-1/4	12-3/4	8-1/2		10-1/2	13-7/8	14-7/8	13-3/8	15-1/4	
Amt. in tanks (Destn)		2-3/8	1/4	1-3/4		1-5/8	2-1/8	1-3/4		3	2-5/8	3-3/8	1-5/8	1-1/4	
Amt. consumed enroute		11-1/4	12-3/4	7-3/8		12-5/8	10-5/8	6-3/4		7-1/2	11-2/8	11-1/2	11-6/8	14	

These figures, representing only one car, are not by any means conclusive, but they indicate that there are certain problems in connection with operating heaters in only one end of a fan car. With a fan operating in the opposite end from the heater, there is danger of a cold pocket in the lower half of the load at the heater end; and with both fans operating there is the probability that much of the heat will circulate in the end containing the heater.

Comparisons of air temperature in a fan car and in a standard car are shown in Figure 14. The standard car (Car V) was loaded on December 15, when outside temperatures were relatively mild; and as a result, the bottom air temperature in Car V was considerably higher after loading than that in Car N, which was loaded when outside temperature was around zero. As the curves show, the top air temperature in Car N rose sharply until the cars started moving; and then dropped materially, as the air was circulated by the fans. Other rises in temperature occurred during the 26 hours the cars were standing in Council Bluffs; and on the night of January 20, while in the Chicago yards. Top air temperatures were consistently higher in Car V than in Car N, and bottom air temperatures were slightly lower in Car V after the initial difference in temperature was equalized.

Potato Temperatures

Car L - Figure 15.

This was a fan car loaded with potatoes that had been pre-warmed for 18 days and were to be maintained at a temperature of about 65° to destination. As the curves show, the top potato temperatures rose to 76° during the time the car was standing at loading point, but dropped below 70° soon after the fans started operating. For the remainder of the trip, the top potato temperatures varied between 63 and 69°.

The potatoes in the middle layer were about 60° when loaded, about 62° when the trip was started, and showed a gradual rise throughout most of the trip to an unloading temperature of about 69°. Potatoes in the bottom layer were 60° or below until January 21, after which they gradually rose to about 68°. It appeared that a thermostat setting of 55° on the automatic heaters was about right for maintaining a load of pre-warmed potatoes at approximately 65° in a fan car. During the period of January 16 through January 20 the outside temperatures were consistently low, and the results indicate that had higher temperatures prevailed during this period excessively high potato temperatures might have occurred when the cars were standing and fans were not operating.

Car M - Figure 16.

These potatoes were pre-warmed for 18 days and loaded into a fan car equipped with one automatic heater set at 34°. There was a general drop in potato temperature until the long stop at Council Bluffs at which time the top and middle layers rose somewhat in temperature. Potatoes in the bottom layer showed a gradual decrease in temperature until January 21, after which they increased gradually to an unloading temperature of about 56°.

Car N - Figure 17.

This was also a fan car equipped with automatic alcohol heaters. Cool storage potatoes were placed in this car, and they were to be warmed to 65° as rapidly as possible. It was originally planned to operate 3 alcohol heaters set at 60° in this car, but the need for a substitute heater in another car interfered with this plan. Consequently, the car was moved with one heater in each bunker. As the chart shows, the potatoes warmed rather slowly, which, however, was to be expected, considering the low outside temperatures to which the cars were exposed for five days after loading. Potatoes in the top layer fluctuated in temperature considerably, following the action of the circulating fans. Top layer potatoes were above 60° most of the time after January 18, and were unloaded at about 68°.

The potatoes in the middle and bottom layers increased in temperature more gradually, and did not reach 60° until January 22. At unloading, these potatoes were about 67°.

Car P - Figure 18.

Potatoes from cool storage were loaded in this car; and as they were to be carried at low temperature, one automatic heater set at 34° was provided for protection against freezing. As the curves show, temperatures below 40° were maintained in the middle and bottom layers until the afternoon of January 23. Temperatures in the top layer varied from 36° to 43° until January 24, after which time they rose quite rapidly to a final temperature of 53°.

Car R - Figure 19.

This was also a fan car, and was loaded with potatoes which had been pre-warmed for 1 week. Two automatic alcohol heaters set at 55° were used to maintain a temperature of 60° to 65° in transit. Potato temperatures in this car were much the same as those in Car L. Sharp rises in top layer temperature occurred while the car was standing; but were equalized quickly when the car was moving. Bottom and middle layer temperatures were between 60° and 65° throughout most of the trip, and 66° to 67° at unloading.

Car S - Figure 20.

The potatoes carried in this car had been pre-warmed for 3 weeks at 65°, and then reduced to 50°--55° for an additional 5 weeks of storage. This was a standard car without circulating fans, and was heated by means of 2 automatic alcohol heaters set at 50°. The potatoes were to be carried at an average temperature of about 65°.

As Figure 20 shows, there was a tremendous spread in potato temperatures in this car, due to the lack of adequate air circulation. Potatoes in the top layer increased in temperature to a high of 76° on January 19 at which time the front heater was extinguised to prevent damage from excessive heat. The top-layer potato temperatures then dropped gradually to about 65°, and averaged 67° at unloading.

The middle-layer potatoes rose in temperature at a rather constant rate from 49° at loading to 64° at unloading.

Due to the low outside temperature and the poor air circulation within the car, the bottom layer decreased slowly in temperature to slightly under 45° on January 20. After this time it increased in temperature gradually to a final average temperature of 57°.

The temperatures obtained in this car showed definitely that the thermostatically controlled heater was not, in itself, the answer to the problem of temperature variation within a car. Response of the thermostat was governed entirely by the temperature of the air immediately adjacent to the thermostat. As the thermostats were located near the floor of the car where temperatures were relatively low, the heaters were burning continuously for the first seven days with a thermostat setting of 50°. Air temperatures near the top of the car were high enough to raise potato temperatures in the top layer to an average at one reading of 76°, while bottom-layer potato temperatures at the same time averaged only 46°. A lower thermostat setting would only have resulted in somewhat lower top and bottom temperatures without decreasing the spread in temperatures. However, previously presented figures have indicated that in the fan cars the thermostatically controlled heaters were of distinct advantage in controlling temperatures, as the air circulation caused by the fans exposed the thermostat to temperature conditions more representative of the entire car.

Car T - Figure 21.

This car was also loaded with potatoes which had been pre-warmed for 3 weeks at 65°, and 5 weeks at 55°. One automatic heater set at 34° was used, as the potatoes were to be cooled in transit. As this car did not have circulating fans, the air temperature at the thermostat location soon dropped low enough to turn on the heater. The result was a gradual rise in top-layer potato temperature for the first three days. During this time the potatoes in the bottom layer dropped below 40°, and potatoes in the middle layer remained about the same. After the third day the heaters burned intermittently and the top-layer potatoes lowered somewhat in temperature. From January 21 to the end of the trip, there was a gradual rise in all potato temperatures, due principally to a distinct moderation in the weather.

Car V - Figure 22.

Potatoes were loaded into this car from a cool storage and were warmed in transit by means of 2 charcoal heaters. The car was without fans, as a result of which top-layer potato temperatures rose rather rapidly to an average of 70° on January 18. During the balance of the trip, the top-layer temperature varied between 70° and 75°. Potatoes in the middle layer increased in temperature at a fairly constant rate, reaching 60° on January 20, 65° on January 23, and 70° at unloading time. Bottom-layer temperatures averaged about 5 degrees lower than those in the middle layer.

Car X - Figure 23.

This standard car was loaded with potatoes from cool storage, and was handled by regular Carriers' Protective Service rules. One or two charcoal heaters, depending upon the outside temperature, were burning throughout the first 3 days of the trip. On January 21, when the outside temperature reached 32°, the ventilators were opened and remained open throughout the rest of the trip. As the curves show, the potato temperature rose slowly while the heaters were operating, dropped sharply when the ventilators were opened, and then increased as the outside air became warmer.

Analyses of Car Atmospheres

Unfortunately, no gas samples were obtained during the first two days of the trip, as moisture had condensed in the copper tubing and frozen so as to block air passage. However, samples were obtained from the standard car with charcoal heaters on January 19, and daily thereafter; and from the fan car with automatic alcohol heaters, beginning on January 21. The record of carbon dioxide, oxygen, and carbon monoxide concentration is shown in Table 16. Car V showed 3.5 percent carbon dioxide, 15.6 percent oxygen, and .3 percent carbon monoxide on January 19. On January 20 the carbon dioxide was lower, and the oxygen was higher. The record of car operation does not account for this difference as the car was closed throughout this period and both charcoal heaters burned continuously. It is possible that a high initial respiratory rate may account for the earlier concentrations. Subsequent readings on Car V were made when only one heater was burning and showed 1.2, 1.5, and 2.3 percent carbon dioxide.

The first reading made on Car N showed 2.0 percent carbon dioxide, 18 percent oxygen, and no carbon monoxide; and later readings showed about the same concentrations.

The gas determinations made on the two test trips indicated that no accumulations of gas sufficient to be harmful to potatoes occurred as a result of charcoal or alcohol heater operation. It is probable that sufficient gas transfer occurs through the car walls to prevent excessive accumulation. The final measure of the effect of the recorded gas concentrations will, of course, be the records of growth and yield secured on potatoes carried in these cars.

Condition at Unloading

Some delay was encountered in unloading the test cars after arrival at destination. Most of the potatoes were unloaded directly into growers' trucks, and intermittent rains prevented the growers from hauling steadily. The result was that the unloading of the nine cars dragged along from the morning of January 26 to mid-morning of January 29.

The cars were in generally good condition when opened with very few bags touching the side wall and very little shifting of the loads. Detailed data on the potatoes are shown in Table 17. There was no freezing damage in any of the cars; and sprouting varied from none in cool potatoes, shipped cool, to sprouts up to 2 inches long on potatoes pre-warmed and shipped warm.

Table 16. Record of Gas Concentrations Obtained in Carloads of Seed Potatoes Shipped from Gering, Nebraska to Robertsdale, Alabama - January 1943.

DATE	TIME	CAR V - STANDARD CAR - CHARCOAL HEATERS				CAR N - FAN CAR - ALCOHOL HEATERS			
		HEATERS OPERATING	CO_2	O_2	CO	HEATERS OPERATING	CO_2	O_2	CO
			Percent	Percent	Percent		Percent	Percent	Percent
Jan. 19	2:00 P.M.	2 burning	3.3	15.6	0.3	2 set at 60°	---	---	---
Jan. 20	5:00 P.M.	2 burning	1.5	19.1	0.2	2 set at 60°	---	---	---
Jan. 21	3:30 P.M.	1 burning	1.2	19.0	0.2	2 set at 60°; burning continuously	2.0	18.0	0
Jan. 22	2:00 P.M.	1 burning	1.5	19.0	0.1	2 set at 60°; burning continuously	2.0	18.2	0
Jan. 23	11:00 A.M.	1 burning	2.3	18.4	0	2 set at 60°; burning intermittently	1.2	18.9	0

Table 17. Record of Unloading Seed Potatoes Shipped from Nebraska to Alabama - January 1943.

CAR	PLACE UNLOADED	DATE UNLOADED	CONDITION OF POTATOES	
			FREEZING	SPROUTING
L	Robertsdale	Jan. 28	none	Starting to 1/8 inch
M	Summerdale	Jan. 27	none	Starting to 1/16 inch
N	Robertsdale	Jan. 27	none	None to starting
P	Summerdale	Jan. 26	none	None
R	Robertsdale	Jan. 28	none	Starting to 1/16 inch
S	Robertsdale	Jan. 28 and 29	none	1/4 to 1/2 in. in bottom layer; 1 to 2 inch in top layer
T	Loxley	Jan. 27	none	1/4 to 1/2 inch
V	Summerdale	Jan. 27 and 28	none	1/4 to 3/4 inch top layer; 1/8 to 1/4 inch bottom layer
X	Foley	Jan. 28	none	Few starting in bottom layer; starting to 1/8 inch in top layer

SUMMARY

Two transportation tests were conducted with Nebraska seed potatoes to determine the effect of storage and transit temperatures on growth and yield in two Southern potato districts.

This report covers only the transit phases of the work, and includes (1) the adaptability of different types of car heaters; (2) the effectiveness of circulating fans; and (3) the practicability of raising potato temperatures in transit.

The first test consisted of nine cars of potatoes (450 sacks each) and moved from Scottsbluff, Nebraska to Russelltown, Texas. Nine cars were also included in the second test which moved from Gering, Nebraska to Robertsdale, Alabama.

Outside temperatures encountered on the first test were moderate, ranging from a low of 24° F. to a high of 76°. In the second test the cars were subjected to sub-zero temperatures for several days.

Results indicated that the increased draught, caused by the circulating fans, tended to cause the charcoal heaters to burn in the fuel magazine, although the evidence on this point was not conclusive.

No evidence was obtained on the operation of the F.G.E. automatic alcohol heaters. They were set at 32° F., and air temperatures within the car did not become sufficiently low during the first test, (when they were used), to operate the heaters.

Potato temperatures obtained in the bottom, middle, and top layers showed that circulating fans materially reduced the difference in potato temperatures in different parts of the car as compared with standard cars.

The P.F.E. automatic alcohol heaters gave good results, particularly when operated in cars containing circulating fans. However, in standard cars there was as great a spread in temperatures in cars heated by thermostatically controlled heaters as in those heated by charcoal heaters.

Evidence was obtained which indicated that the operation of a heater in one end of a fan car creates problems in air circulation. When both fans were operated, the warm air tended to circulate in the end of the car containing the heater. When only the fan at the opposite end from the heater was operated, a cold pocket was created near the floor in the heater end of the car.

From 6 to 7 days were required to warm a 45,000-pound load of potatoes from an average temperature of 42° F. to an average temperature of 65° by means of 2 charcoal or alcohol heaters.

The "Pyramid Through Load" carried very well with very little shifting of sacks, and good air channels were maintained around the load.

Analysis of the atmospheres inside several cars during the transit period showed carbon dioxide concentrations ranging from 1.2 to 4.8 percent with one or two charcoal heaters burning. Oxygen concentrations were reduced in amounts roughly equivalent to the increase in carbon dioxide. Concentrations of carbon dioxide up to 2 percent were found in a car in which two alcohol heaters were operating.

The potatoes were all in good condition when unloaded. No evidence of freezing was found, and the amount of sprouting was in direct relationship to the temperatures under which the potatoes had been stored and transported.

PERSONNEL OF TEST TRIPS

First Test - Nebraska to Texas

A. Lloyd Ryall Assoc. Pomologist	Bureau of Plant Industry Harlingen, Texas	Scottsbluff, Nebraska To Russelltown, Texas
A. A. Hamer General Mech. Insp.	Fruit Growers Express Co. Alexandria, Virginia	Scottsbluff, Nebraska To Russelltown, Texas
H. B. Meinhardt Gen'l Agent, Perish. Tr.	Chicago, Burlington & Quincy R.R. Chicago, Illinois	Scottsbluff, Nebraska To Kansas City, Mo.
O. E. Pearson Ass't. Supt. of Trans.	Chicago, Burlington &Quincy R.R. Chicago, Illinois	Scottsbluff, Nebraska To Kansas City, Mo.
A. K. Hepperly Agricultural Agent	Chicago, Burlington &Quincy R.R. Denver, Colorado	Scottsbluff, Nebraska To Kansas City, Mo.
J. R. Giegerich Supervisor of Service	Burlington Refrig. Express Co. Chicago, Illinois	Scottsbluff, Nebraska To Kansas City, Mo.
J. M. Lutz Assoc. Physiologist	Bureau of Plant Industry Meridian, Mississippi	Kansas City, Missouri To Russelltown, Texas
J. T. Bradford Traveling Frgt. Agent	American Refrig. Transit Co. San Antonio, Texas	Kansas City, Missouri To Russelltown, Texas
H. A. Black Service Inspector	Fruit Growers Express Co. Alexandria, Virginia	Kansas City, Missouri To Russelltown, Texas

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Second Test - Nebraska to Alabama

A. Lloyd Ryall Assoc. Pomologist	Bureau of Plant Industry Harlingen, Texas	Gering, Nebraska To Robertsdale, Ala.
J. M. Lutz Assoc. Physiologist	Bureau of Plant Industry Meridian, Mississippi	Gering, Nebraska To Robertsdale, Ala.
R. A. Doering Test Engineer	Pacific Fruit Express Co. San Francisco, California	Gering, Nebraska To Gulfport, Mississippi
F. C. Paulsen Gen. Mgr. Eastern Dist.	Union Pacific R. R. Omaha, Nebraska	Gering, Nebraska To Omaha, Nebraska
T. H. Alexander Agricultural Agent	Union Pacific R. R. Omaha, Nebraska	Gering, Nebraska To Omaha, Nebraska
J. D. Tuttle Supt. Perishable Freight Service	Illinois Central R. R. Chicago, Illinois	Council Bluffs, Iowa To Gulfport, Mississippi
H. A. Black Service Inspector	Fruit Growers Express Co. Alexandria, Virginia	Gulfport, Mississippi To Robertsdale, Ala.

****

ACKNOWLEDGEMENTS

The cooperation of the following organizations and persons in planning and conducting the two transportation tests is gratefully acknowledged:

The Nebraska Certified Seed Potato Growers Cooperative and the officials and directors of that organization who gave liberally of their time and expended a considerable sum of money in setting up the project and in providing facilities for its successful conduct; Mr. Howard McLean of the above organization whose efforts made the loading of the test possible and Messrs. Charles Barbour, Carl Ehrman and Harley Shaver who raised, stored and loaded the potatoes carried in the test cars.

The Chicago, Burlington and Quincy Railroad and particularly Messrs. H. B. Meinhardt and George F. Jones through whose efforts the accommodations for those accompanying the first test trip were obtained. The Union Pacific Railroad and especially Mr. J. W. Jarvis, Supervisor of Agricultural Development, who arranged for accommodations on the second trip and was very helpful with last minute changes in schedule made necessary by requests from the receivers for earlier delivery. The Illinois Central Railroad and Mr. J. D. Tuttle of that organization who arranged for accommodations and accompanied the second test from Council Bluffs to Gulfport. The Missouri Pacific and the Louisville and Nashville Railroads whose representatives were helpful in arranging and conducting the tests. The Fruit Growers Express, Burlington Refrigerator Express, Pacific Fruit Express and American Refrigerator Transit Companies who furnished comparable refrigerator cars, heaters, fuel, etc., and whose representatives were extremely helpful in the conduct of the tests.

The receivers in Texas and Alabama; Porter and Wentz of Brownsville, Texas; A. A. Cortee and Son of Loxley, Alabama; Bill Baldwin of Robertsdale, Alabama, and others all of whom were helpful in the orderly unloading of the test cars. Representatives of the Valley Experiment Substation at Weslaco, Texas and the Gulf Coast Substation at Fairhope, Alabama who assisted in recovering equipment and test bags from the test cars and conducted the planting tests with potatoes from each of the test cars.

Figure 1. Photograph of one of the test cars during loading showing detail of the "Pyramid Through Load." Picture by courtesy of the Union Pacific R. R.

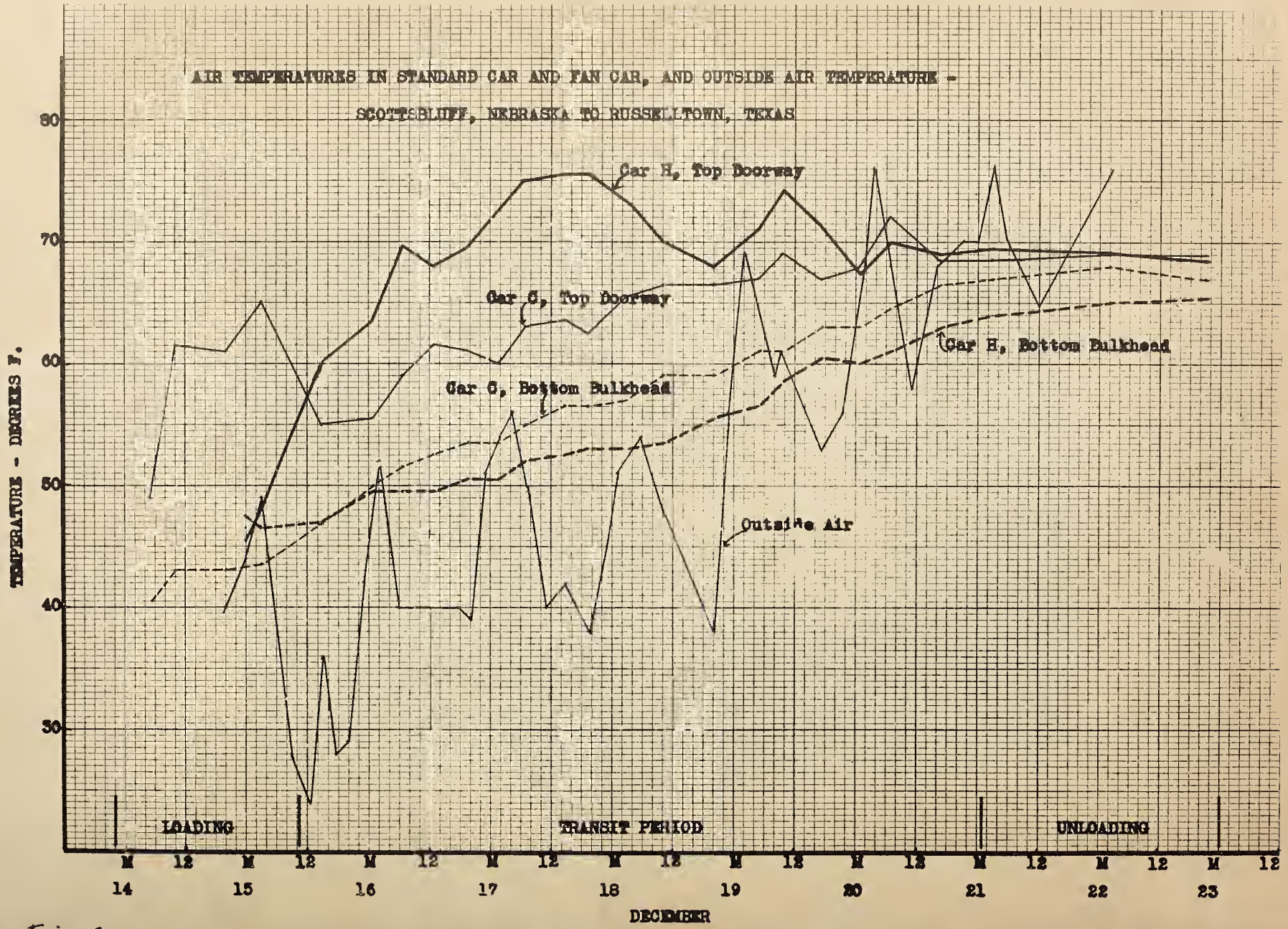

AIR TEMPERATURES IN STANDARD CAR AND FAN CAR, AND OUTSIDE AIR TEMPERATURE -
SCOTTSBLUFF, NEBRASKA TO RUSSELLTOWN, TEXAS
Car H, Top Doorway
Car C, Top Doorway
Car H, Bottom Bulkhead
Car C, Bottom Bulkhead
Outside Air
TEMPERATURE - DEGREES F.
80
70
60
50
40
30
LOADING
TRANSIT PERIOD
UNLOADING
M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M
14 15 16 17 18 19 20 21 22 23
DECEMBER

Figure 2

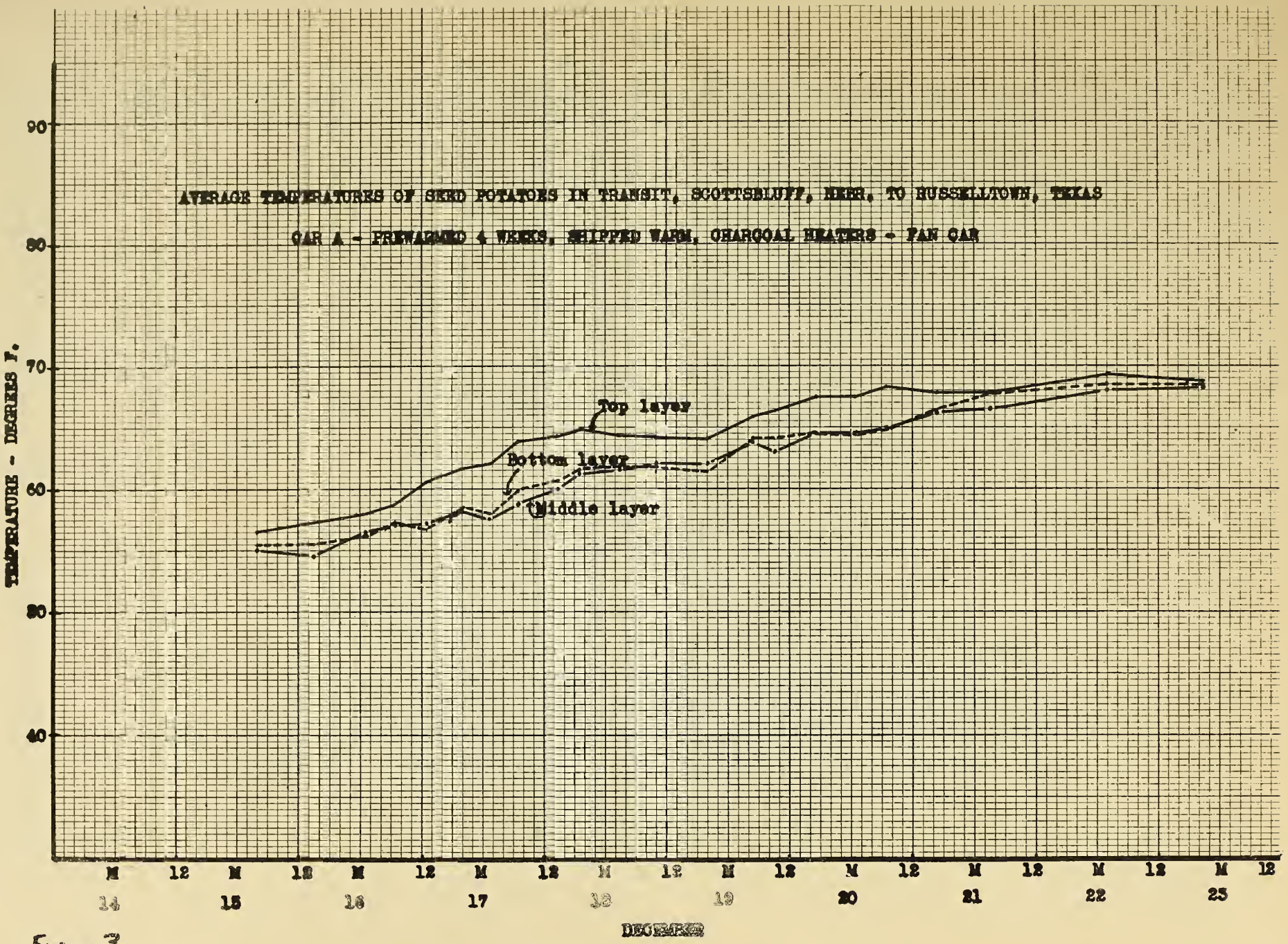
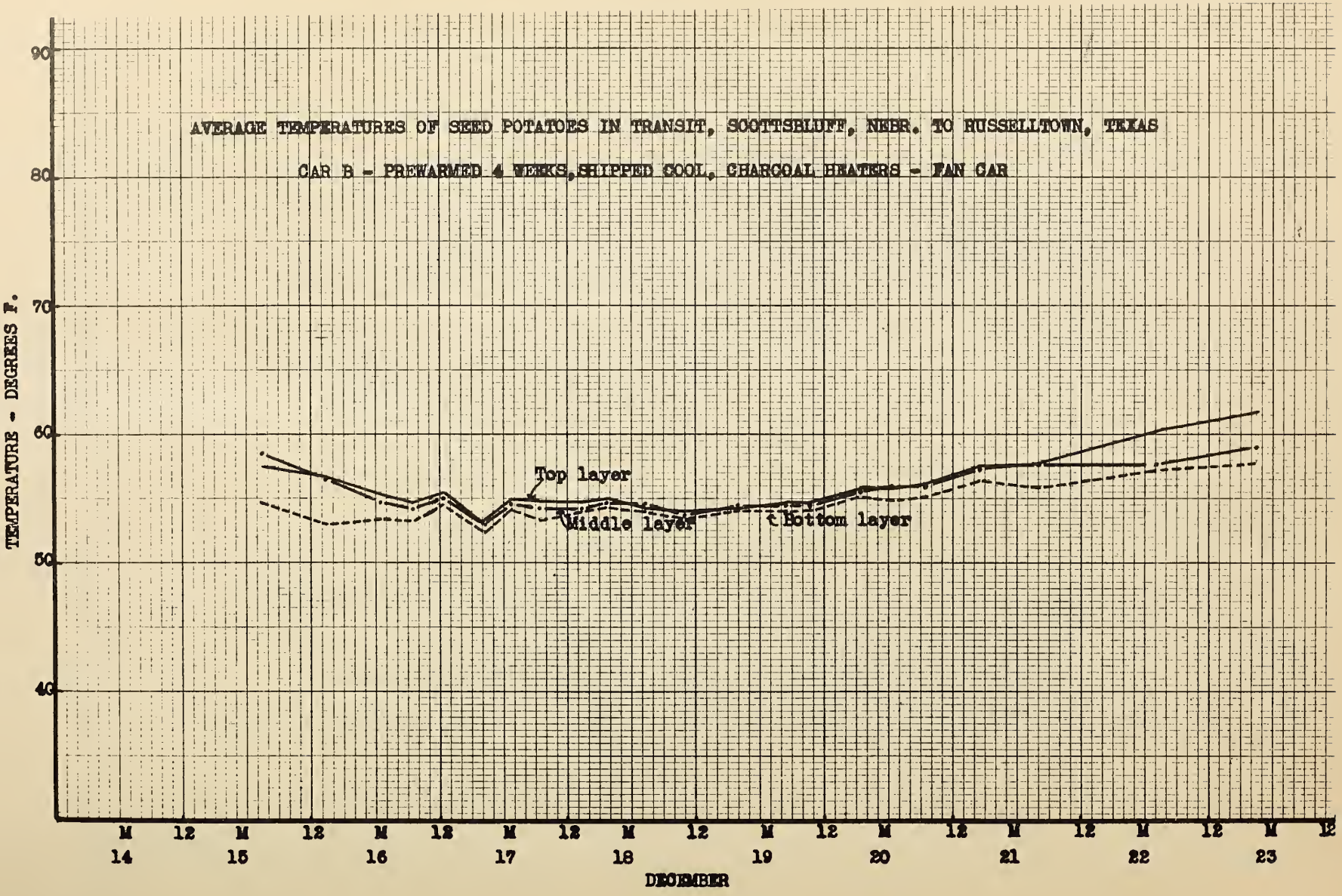
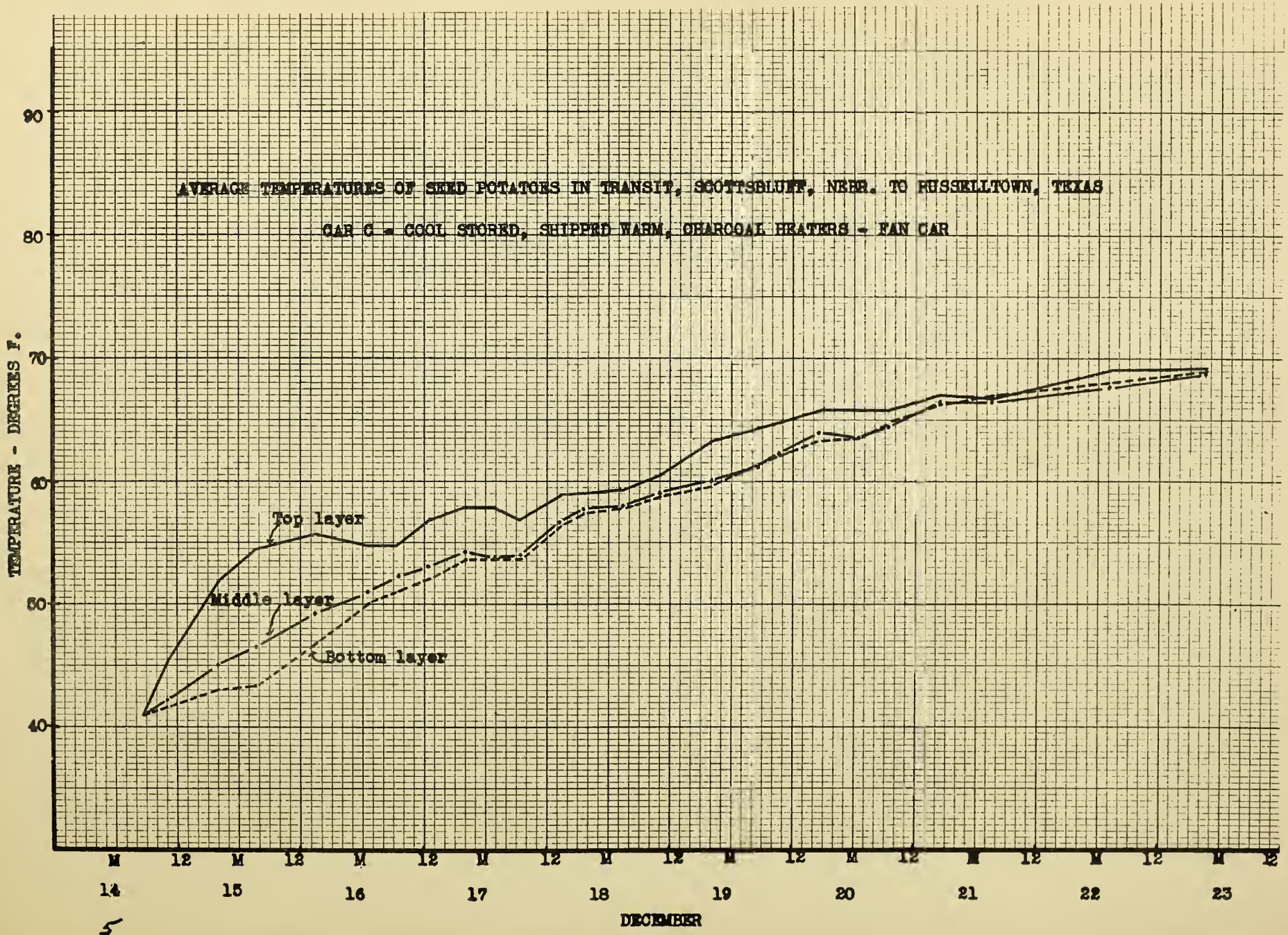

AVERAGE TEMPERATURES OF SEED POTATOES IN TRANSIT, SCOTTSBLUFF, NEBR. TO RUSSELLTOWN, TEXAS
CAR A - PREWARMED 4 WEEKS, SHIPPED WARM, CHARCOAL HEATERS - FAN CAR
TEMPERATURE - DEGREES F.
90
80
70
60
50
40
Top layer
Bottom layer
Middle layer
M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12
14 15 16 17 18 19 20 21 22 23
DECEMBER

Figure 3


AVERAGE TEMPERATURES OF SEED POTATOES IN TRANSIT, SCOTTSBLUFF, NEBR. TO RUSSELLTOWN, TEXAS
CAR B - PREWARMED 4 WEEKS, SHIPPED COOL, CHARCOAL HEATERS - FAN CAR
TEMPERATURE - DEGREES F.
90
80
70
60
50
40
Top layer
Middle layer
Bottom layer
M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M
14 15 16 17 18 19 20 21 22 23
DECEMBER

AVERAGE TEMPERATURES OF SEED POTATOES IN TRANSIT, SCOTTSBLUFF, NEBR. TO RUSSELLTOWN, TEXAS

CAR C - COOL STORED, SHIPPED WARM, CHARCOAL HEATERS - FAN CAR



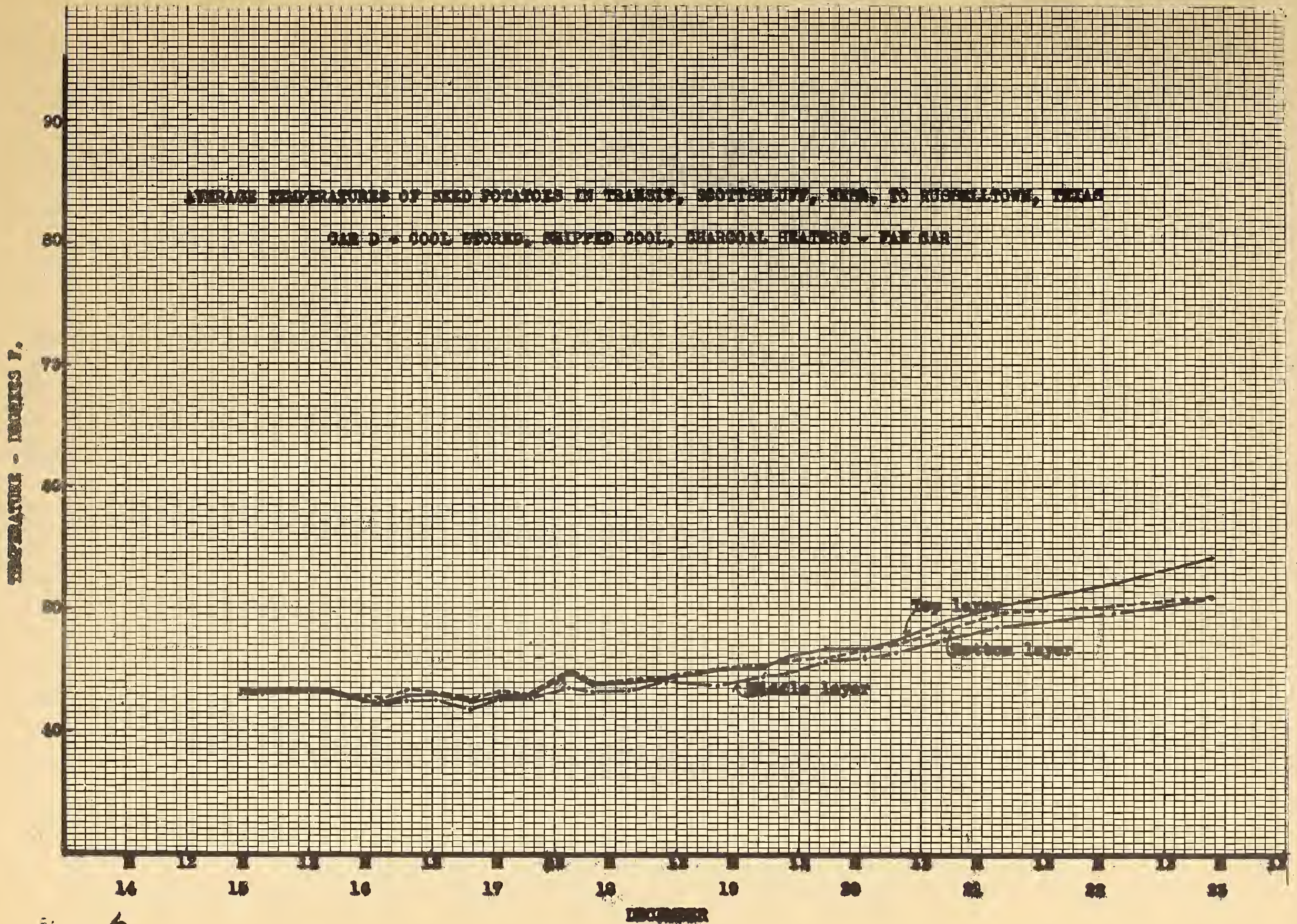

AVERAGE TEMPERATURES OF SEED POTATOES IN TRANSIT, SCOTTSBLUFF, NEBR., TO RUSSELLTOWN, TEXAS
CAR D - COOL STORED, SHIPPED COOL, CHARCOAL HEATERS - FAN CAR
TEMPERATURE - DEGREES F.
90
80
70
60
50
40
Top layer
Bottom layer
Middle layer
14
15
16
17
18
19
20
21
22
23
DECEMBER

Figure 6

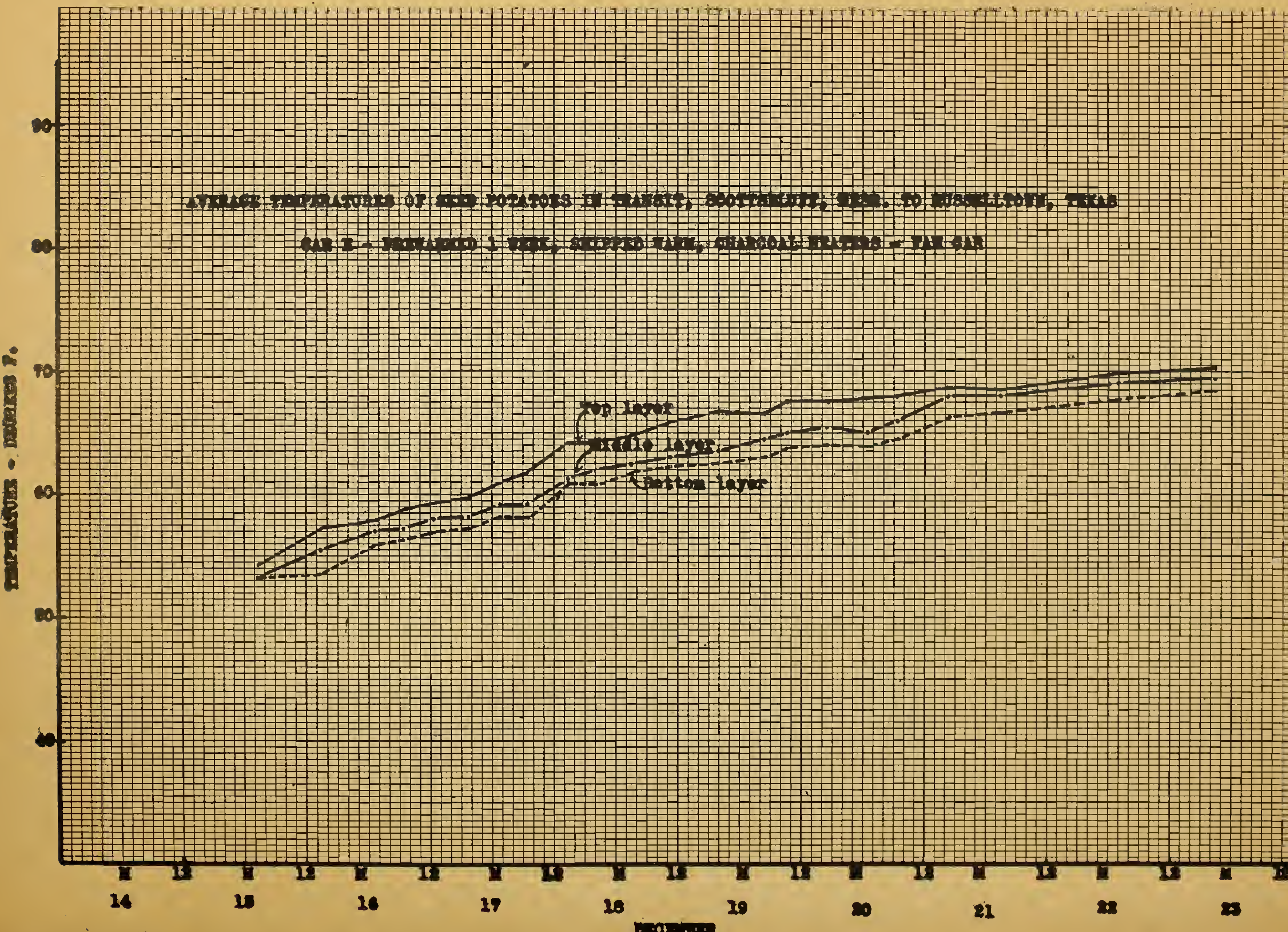
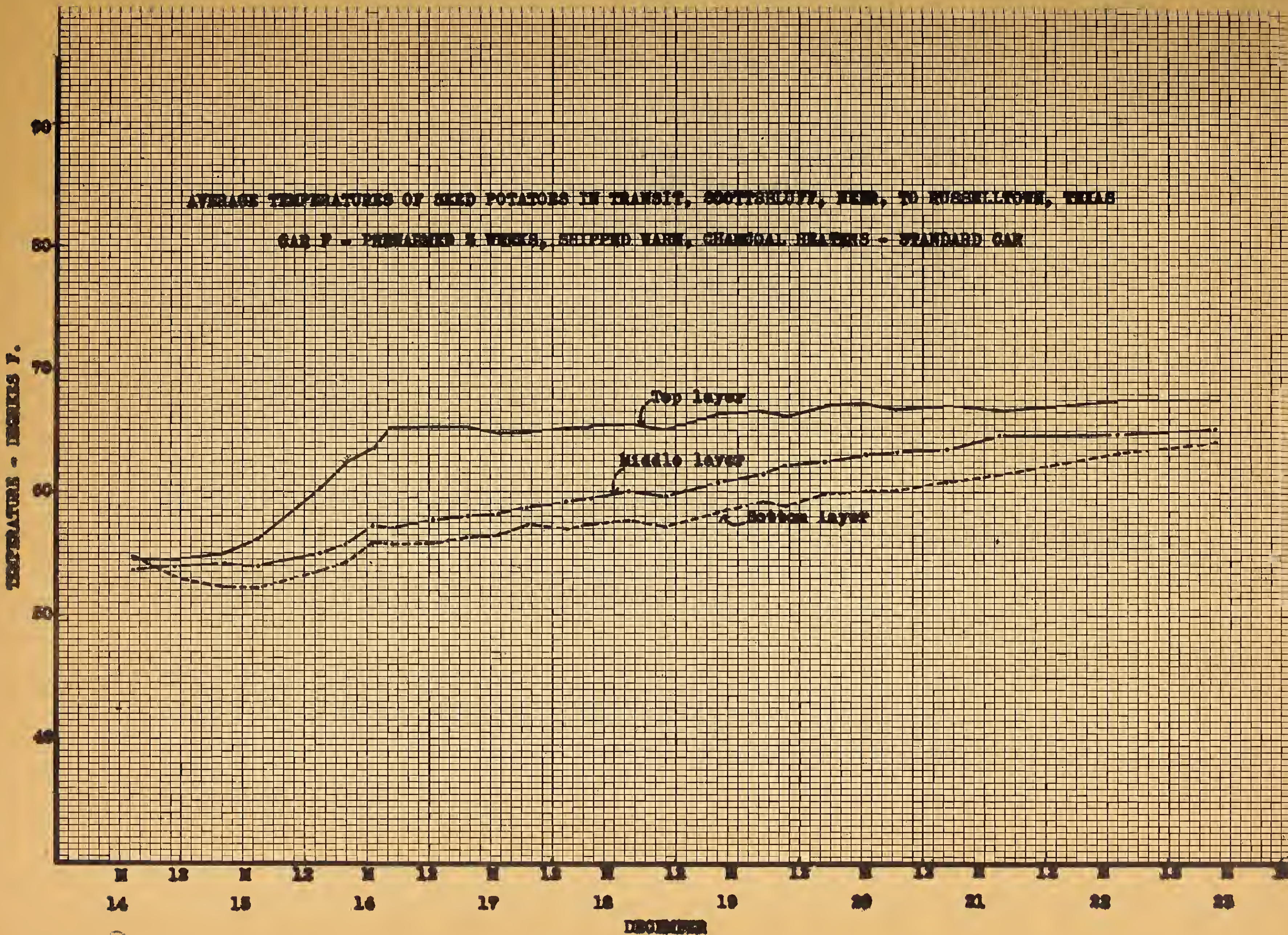

TEMPERATURE - DEGREES F.
40
50
60
70
80
90
Top layer
Middle layer
Bottom layer
14
15
16
17
18
19
20
21
22
23
DECEMBER

Figure 7



AVERAGE TEMPERATURES OF SEED POTATOES IN TRANSIT, SCOTTSBLUFF, NEBR., TO
TEXAS
CAR F - PREWARMED 2 WEEKS, SHIPPED WARM, CHARCOAL HEATERS - STANDARD CAR
Top layer
Middle layer
Bottom layer
TEMPERATURE - DEGREES F.
40
50
60
70
80
90
14
15
16
17
18
19
20
21
22
23
DECEMBER

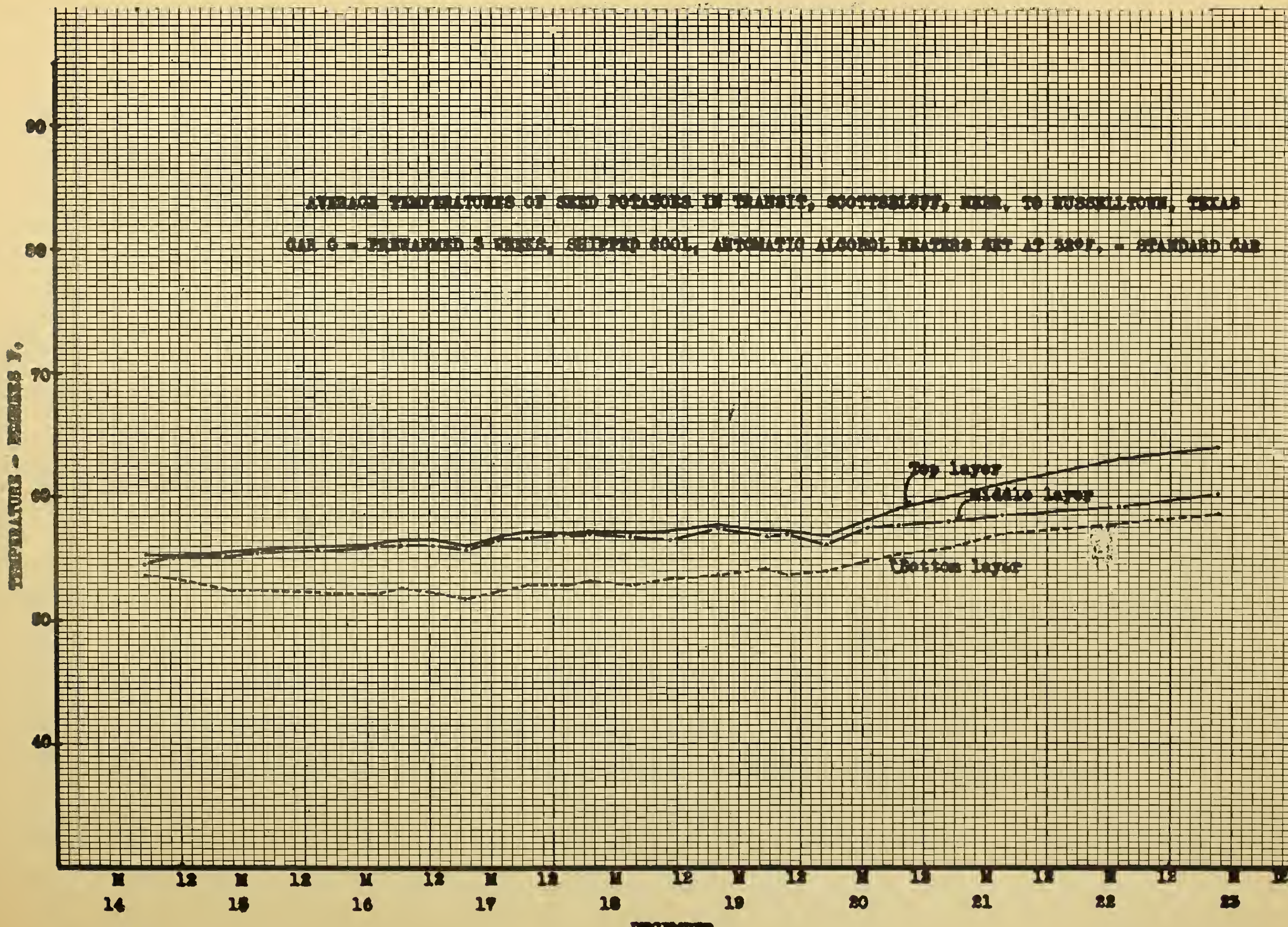
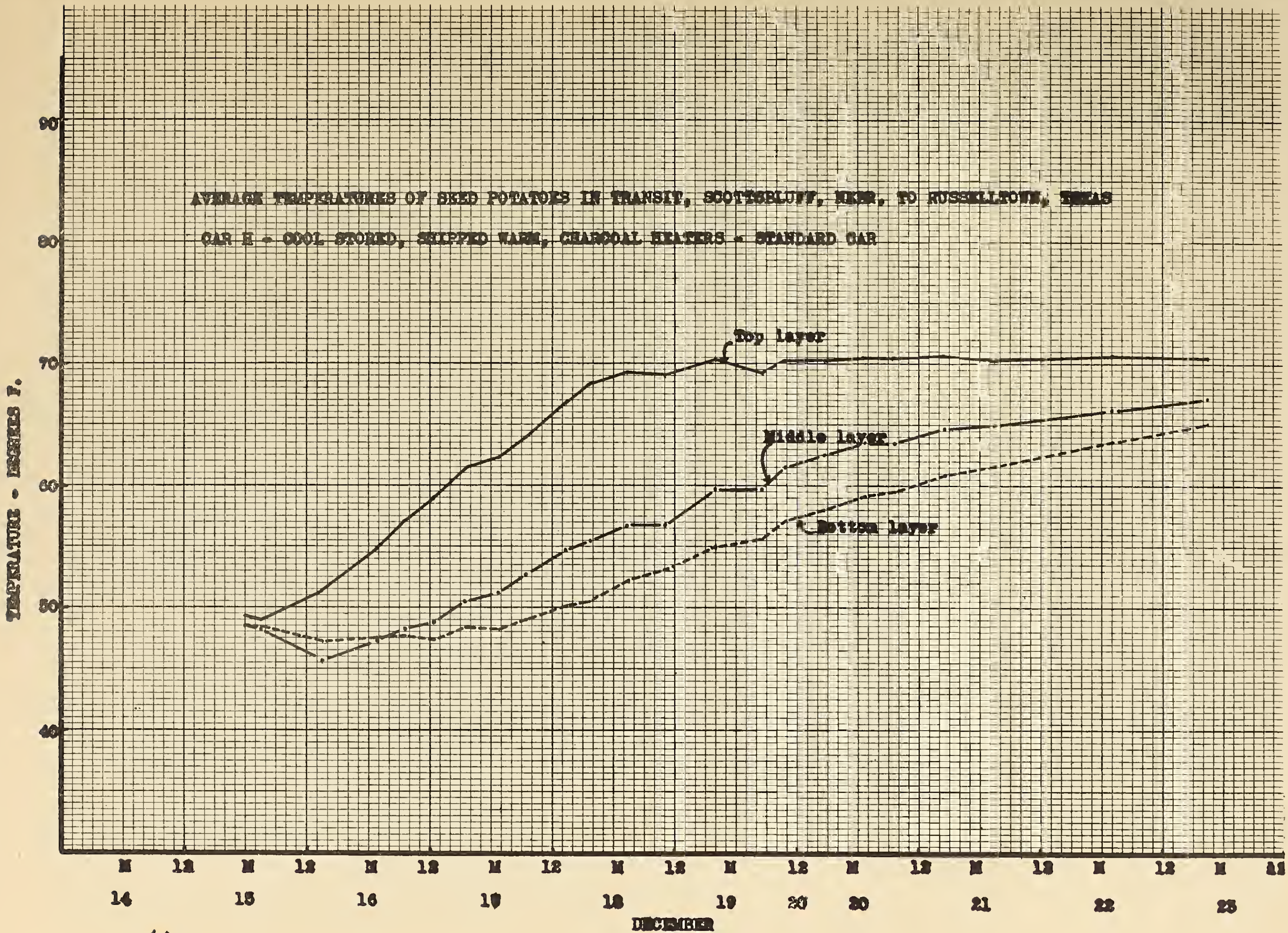
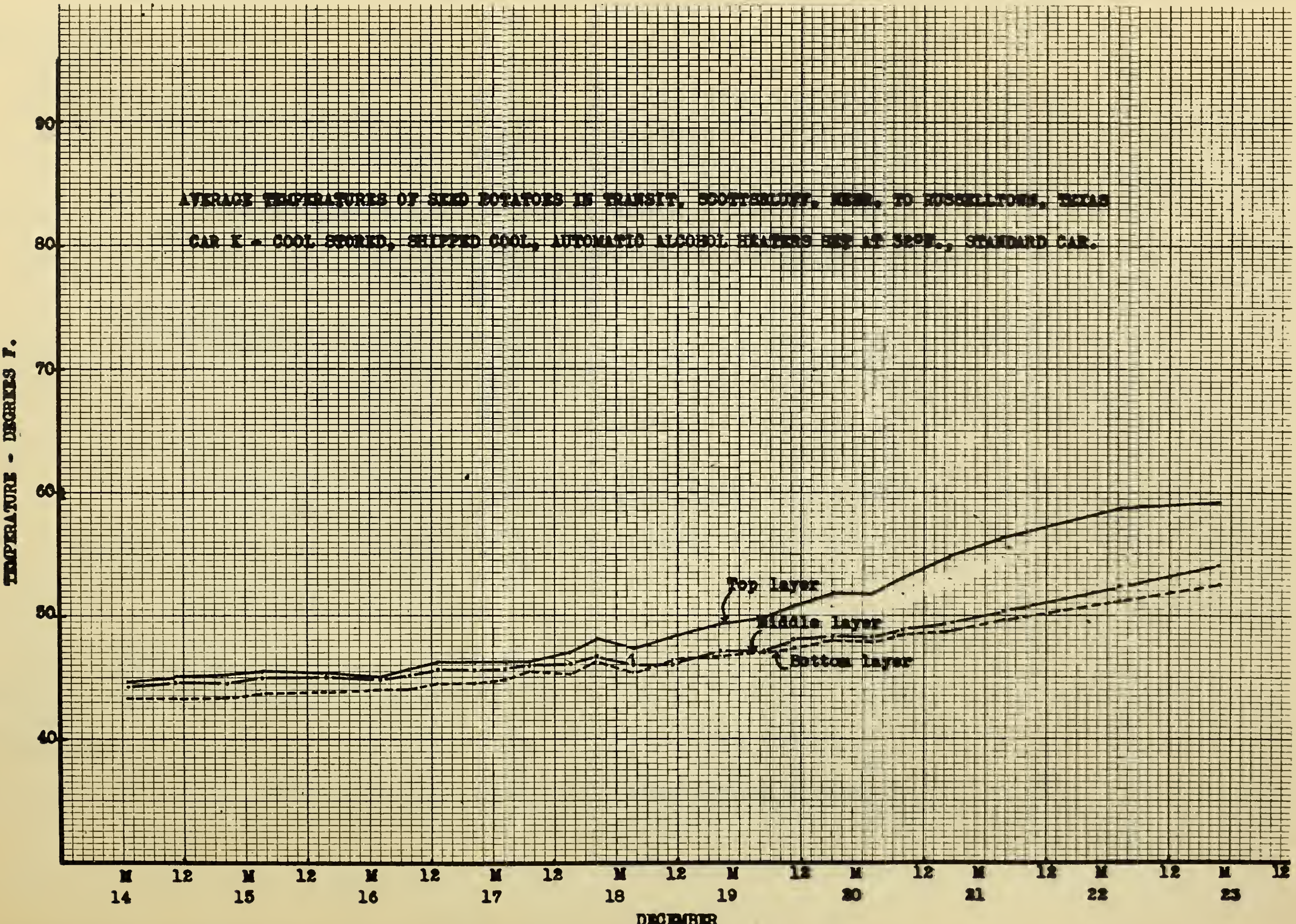

AVERAGE TEMPERATURES OF SEED POTATOES IN TRANSIT, SCOTTSBLUFF, NEBR, TO RUSSELLTOWN, TEXAS
CAR G - PREWARMED 3 WEEKS, SHIPPED COOL, AUTOMATIC ALCOHOL HEATERS SET AT 32°F. - STANDARD CAR
TEMPERATURE - DEGREES F.
90
80
70
60
50
40
Top layer
Middle layer
Bottom layer
M
12
14
15
16
17
18
19
20
21
22
23
DECEMBER

Figure 9



AVERAGE TEMPERATURES OF SEED POTATOES IN TRANSIT, SCOTTSBLUFF, NEBR, TO RUSSELLTOWN, TEXAS
CAR H - COOL STORED, SHIPPED WARM, CHARCOAL HEATERS - STANDARD CAR
Top layer
Middle layer
Bottom layer
TEMPERATURE - DEGREES F.
90
80
70
60
50
40
DECEMBER
14
15
16
17
18
19
20
21
22
23

10

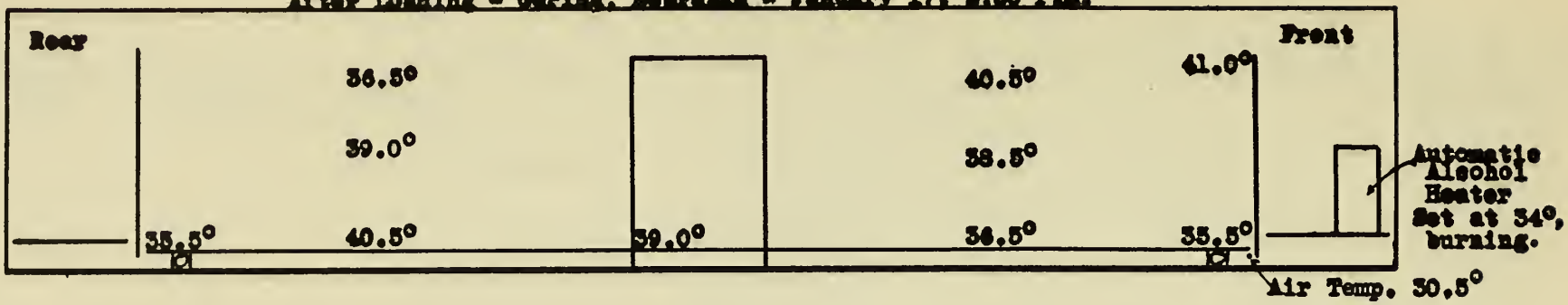

AVERAGE TEMPERATURES OF SEED POTATOES IN TRANSIT, SCOTTSBLUFF, NEBR., TO TEXAS
CAR K - COOL STORED, SHIPPED COOL, AUTOMATIC ALCOHOL HEATERS AT 32°F., STANDARD CAR.
TEMPERATURE - DEGREES F.
90
80
70
60
50
40
Top layer
Middle layer
Bottom layer
M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12
14 15 16 17 18 19 20 21 22 23
DECEMBER

TEMPERATURE - DEGREES
JANUARY
RECORD OF OUTSIDE AIR TEMPERATURES AT CENTRAL HEATING PLANT, MONTGOMERY, ALABAMA

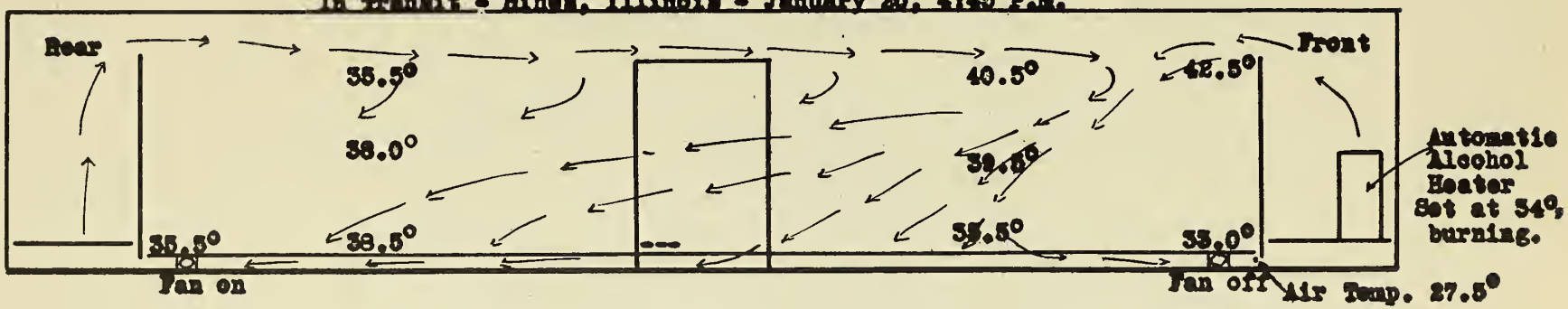
THE EFFECT OF FAN & HEATER OPERATION ON POTATO TEMPERATURES IN DIFFERENT PARTS OF THE LOAD.

GERING, NEBRASKA TO ROBERTSDALE, ALABAMA.

After Loading - Gering, Nebraska - January 17, 8:30 P.M.

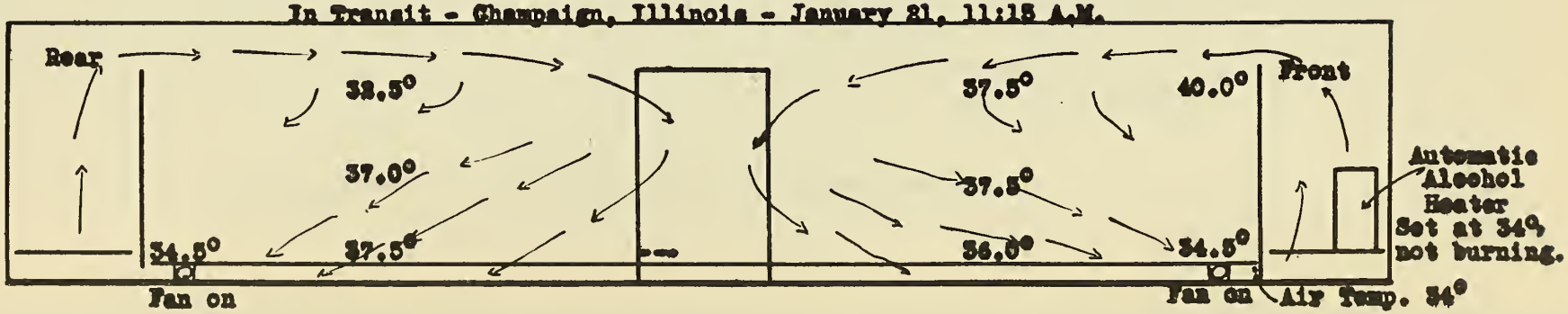


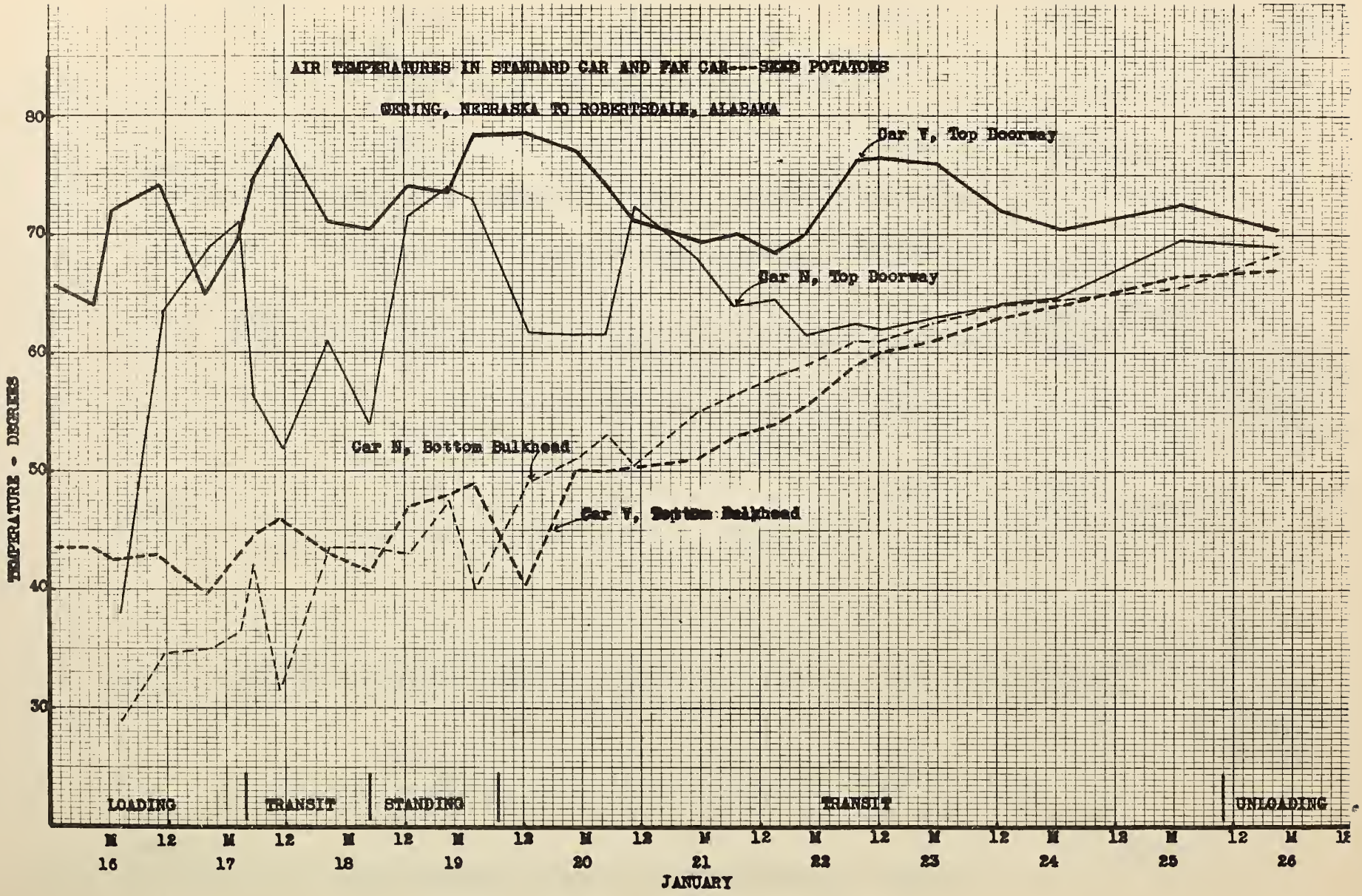
In Transit - Hinsa, Illinois - January 20, 4:45 P.M.



Front Fan Turned on at Chicago, January 20, 5:00 P.M.

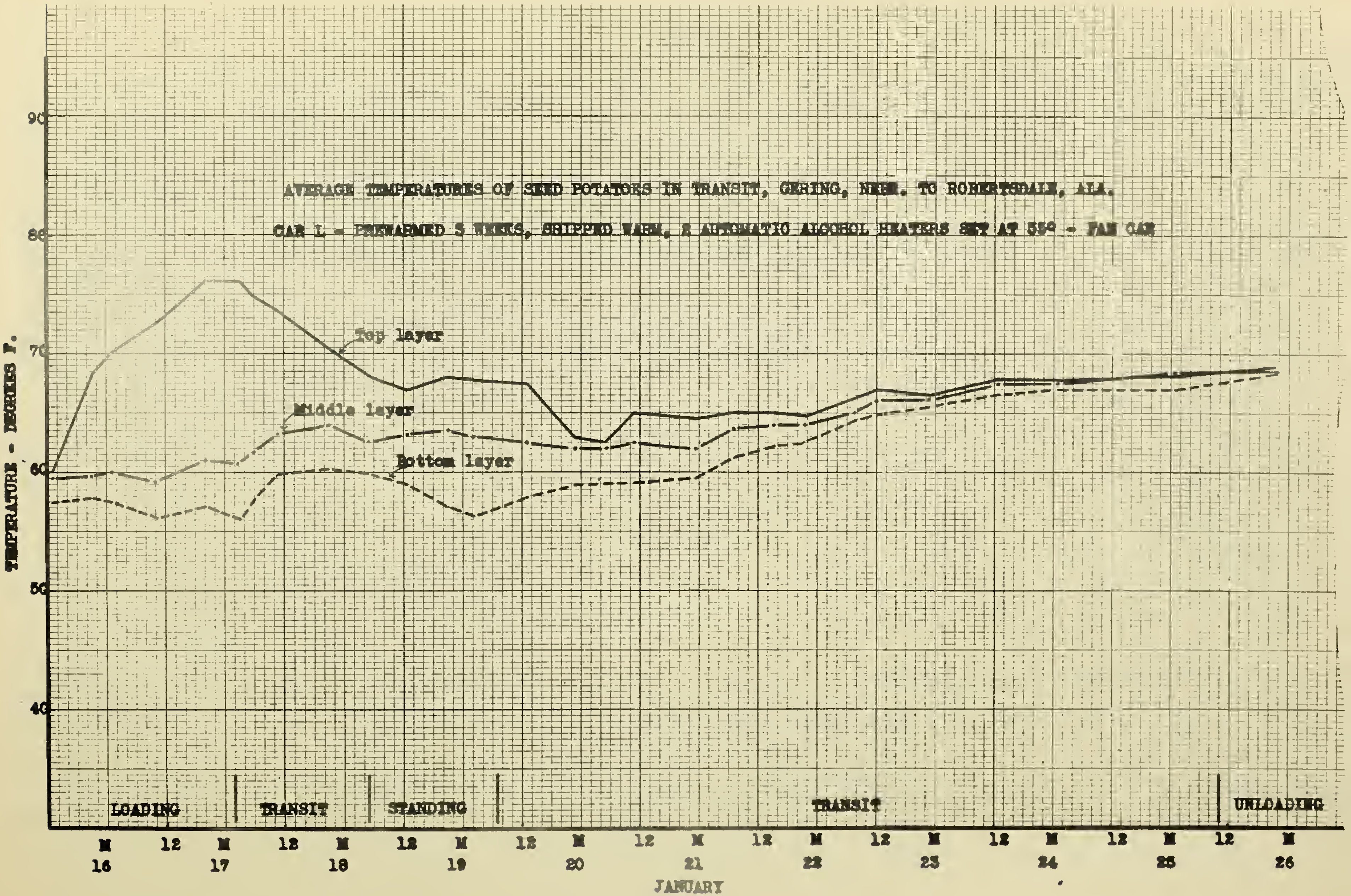
In Transit - Champaign, Illinois - January 21, 11:15 A.M.




AIR TEMPERATURES IN STANDARD CAR AND FAN CAR---SEED POTATOES
GERING, NEBRASKA TO ROBERTSDALE, ALABAMA
Car V, Top Doorway
Car N, Top Doorway
Car N, Bottom Bulkhead
Car V, Bottom Bulkhead
TEMPERATURE - DEGREES
80
70
60
50
40
30
LOADING
TRANSIT
STANDING
TRANSIT
UNLOADING
M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M
16 17 18 19 20 21 22 23 24 25 26
JANUARY

AVERAGE TEMPERATURES OF SEED POTATOES IN TRANSIT, GERING, NEBR. TO ROBERTSDALE, ALA.

CAR L - PREWARMED 3 WEEKS, SHIPPED WARM, 2 AUTOMATIC ALCOHOL HEATERS SET AT 55° - FAN CAR



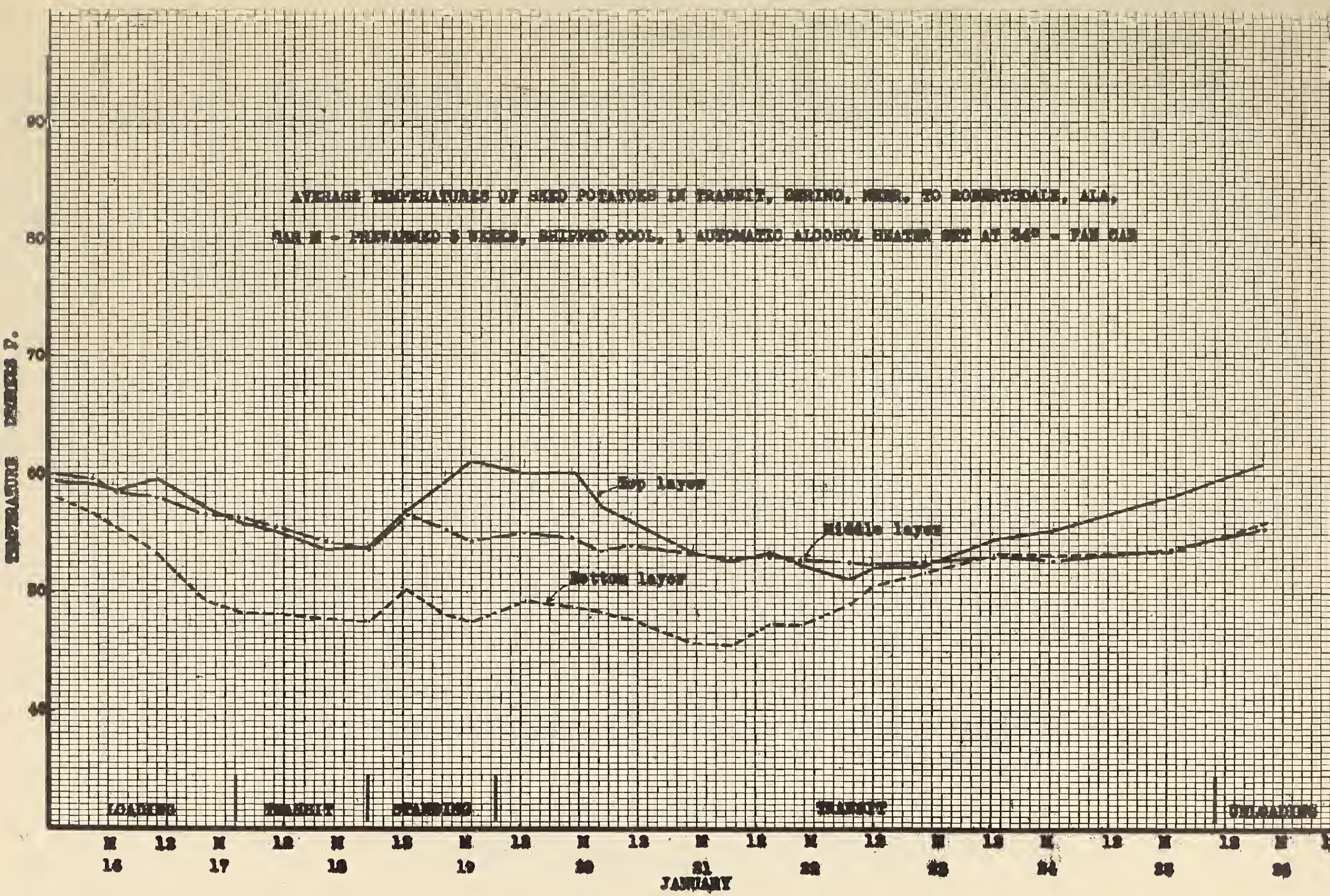
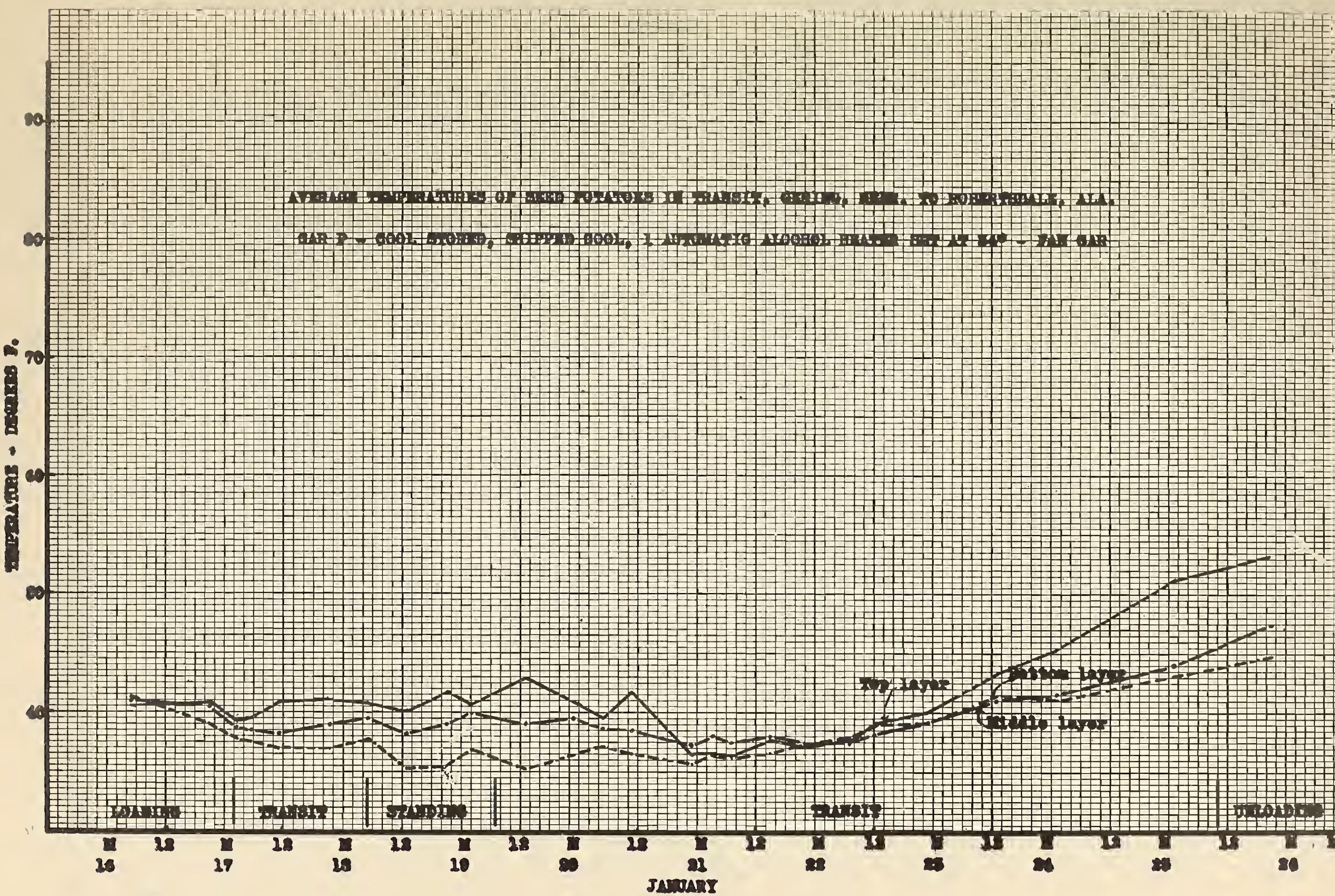
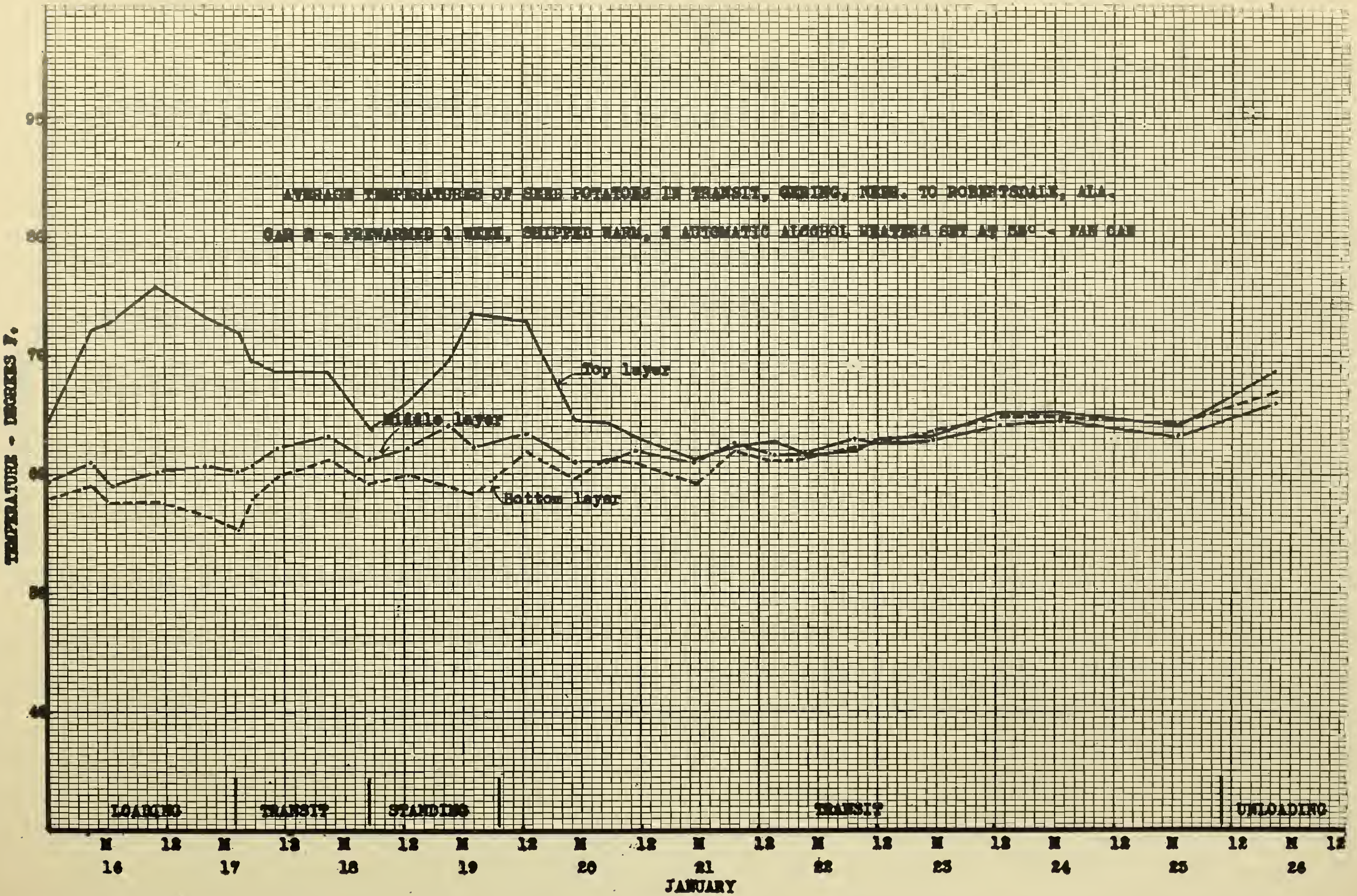

AVERAGE TEMPERATURES OF SEED POTATOES IN TRANSIT, GERING, NEBR., TO ROBERTSDALE, ALA.
CAR M - PREWARMED 3 WEEKS, SHIPPED COOL, 1 AUTOMATIC ALCOHOL HEATER SET AT 34° - FAN CAR
TEMPERATURE DEGREES F.
90
80
70
60
50
40
Top layer
Middle layer
Bottom layer
LOADING
TRANSIT
STANDING
TRANSIT
UNLOADING
M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M
16
17
19
21
JANUARY
24

Figure 16

TEMPERATURE - DEGREES F.
TOP TUBE
MIDDLE TUBE
BOTTOM TUBE



AVERAGE TEMPERATURES OF SEED POTATOES IN TRANSIT, GERING, NEBR. TO ROBERTSDALE, ALA.
CAR F - COOL STORED, SHIPPED COOL, 1 AUTOMATIC ALCOHOL HEATER SET AT 34° - FAN CAR
TEMPERATURE - DEGREES F.
90
80
70
60
50
40
Top layer
Bottom layer
Middle layer
LOADING
TRANSIT
STANDING
TRANSIT
UNLOADING
M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12 M 12
16 17 18 19 20 21 22 23 24 25 26
JANUARY


AVERAGE TEMPERATURES OF SEED POTATOES IN TRANSIT, GERING, NEBR. TO ROBERTSDALE, ALA.
CAR 2 - PREWARMED 1 WEEK, SHIPPED WARM, 2 AUTOMATIC ALCOHOL HEATERS SET AT
FAN CAR
TEMPERATURE - DEGREES F.
95
70
Top layer
Middle layer
Bottom layer
LOADING
TRANSIT
STANDING
TRANSIT
UNLOADING
M
12
16
17
18
19
20
21
22
23
24
25
26
JANUARY

19

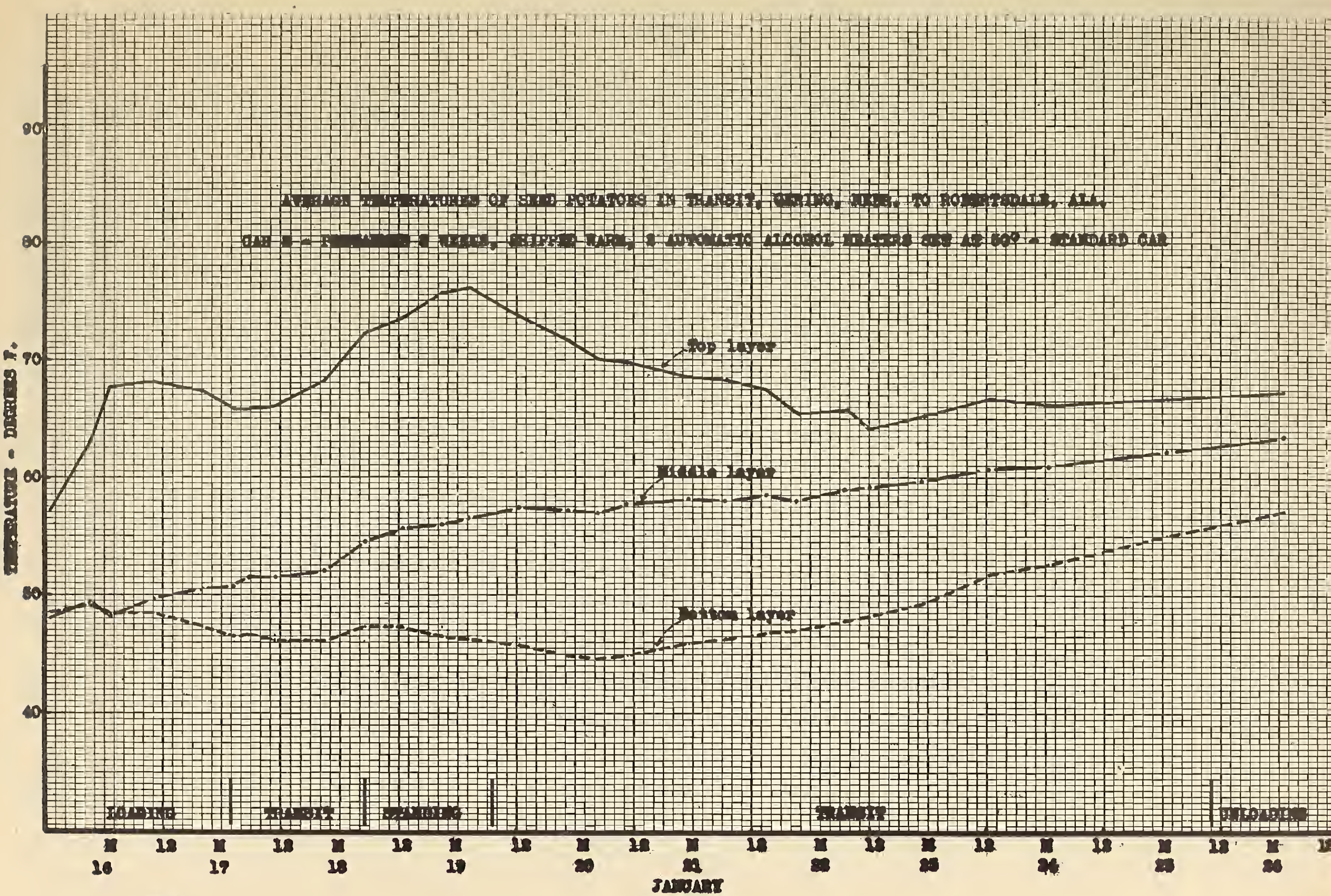
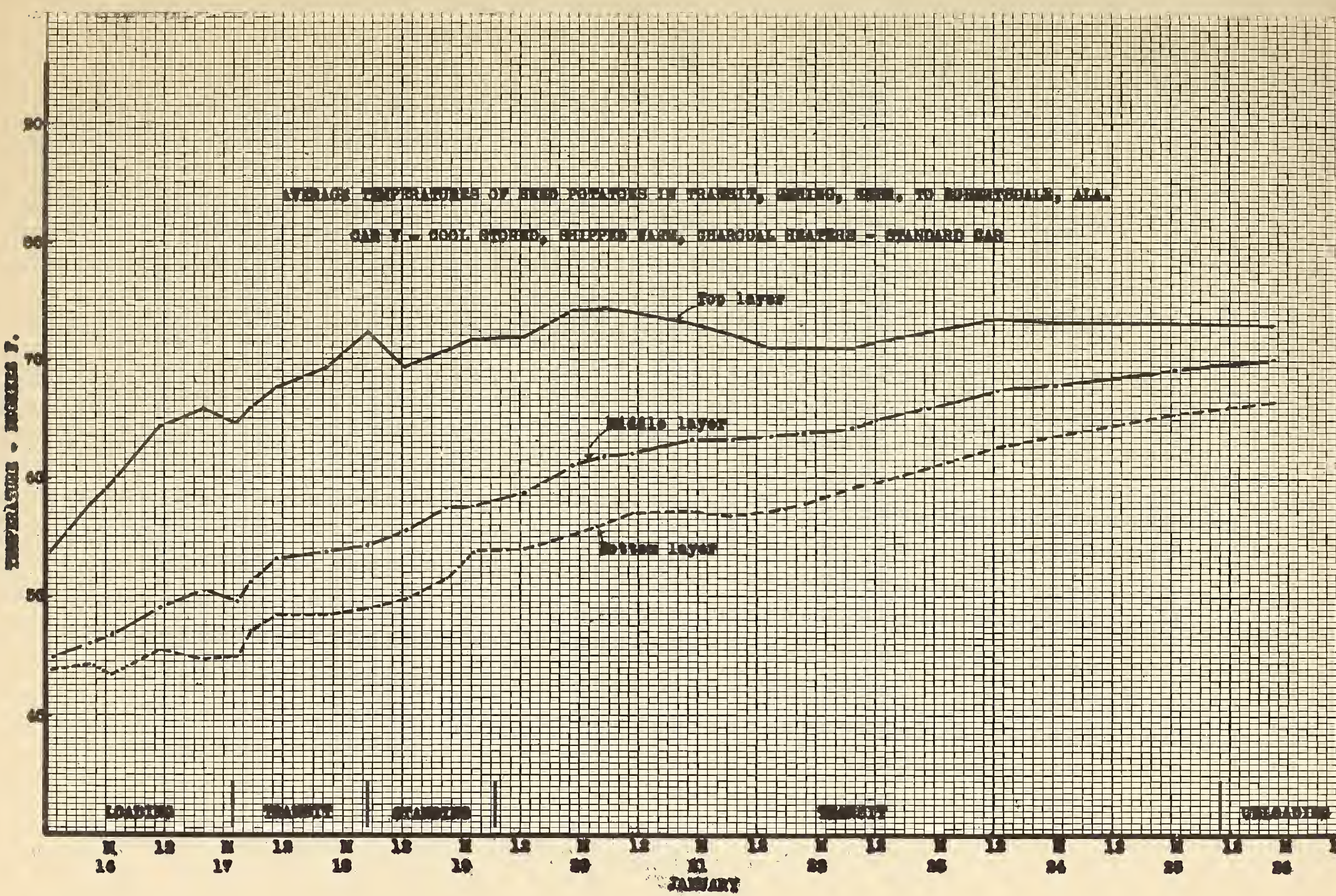
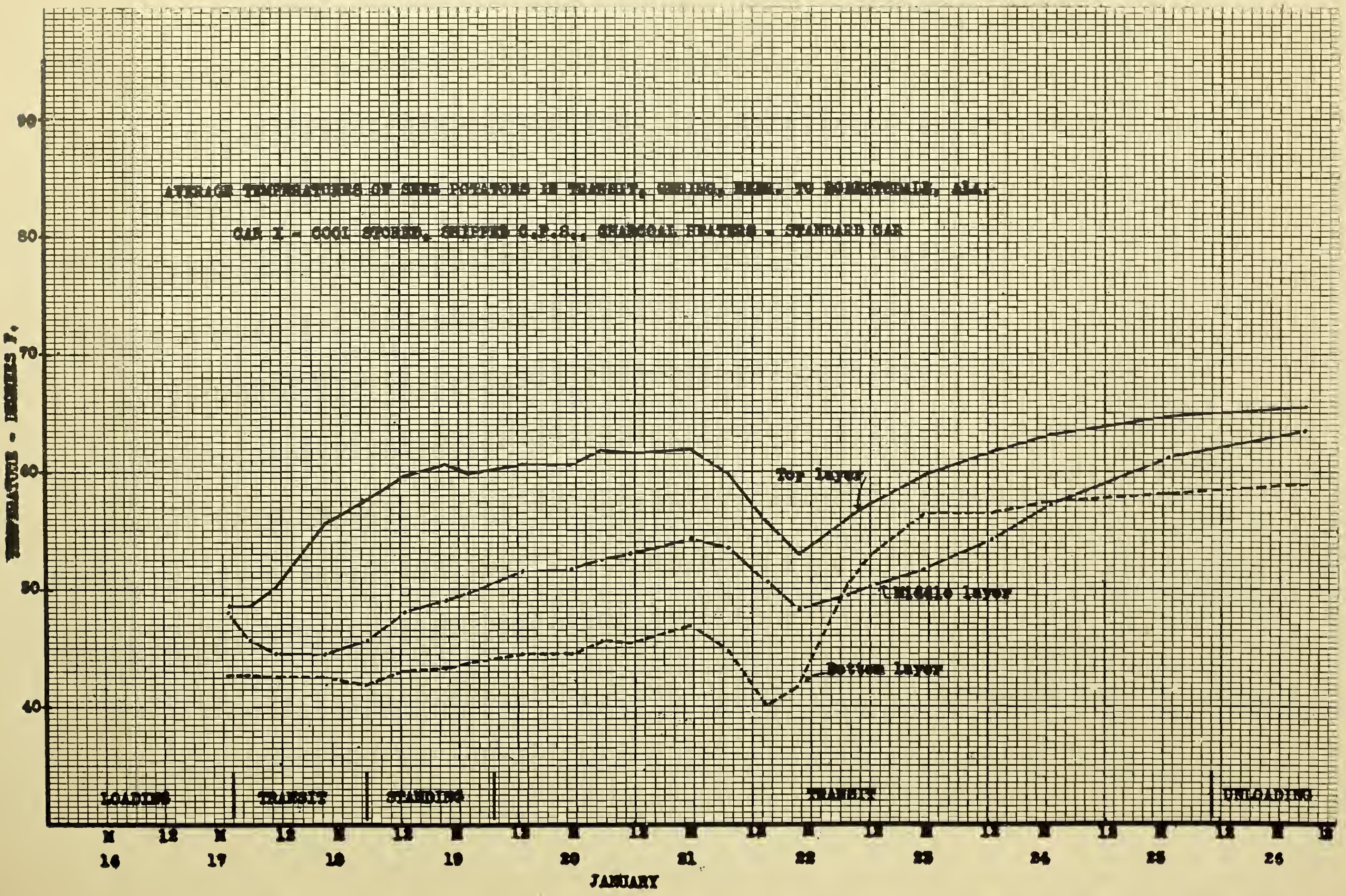

AVERAGE TEMPERATURES OF SEED POTATOES IN TRANSIT, GERING, NEBR. TO ROBERTSDALE, ALA.
SHIPPED WARM, 2 AUTOMATIC ALCOHOL HEATERS SET AT 50° - STANDARD CAR
TEMPERATURE - DEGREES F.
90
80
70
60
50
40
Top layer
Middle layer
Bottom layer
LOADING
TRANSIT
TRANSIT
UNLOADING
M
12
16
17
18
19
20
21
22
23
24
25
26
JANUARY

Figure 20

TEMPERATURE - DEGREES F.
JANUARY
DEEP LAYER
MIDDLE LAYER
SURFACE LAYER


Top layer
Middle layer
Bottom layer
TEMPERATURE - DEGREES F.
LOADING
TRANSIT
STANDING
TRANSIT
UNLOADING
JANUARY


AVERAGE TEMPERATURES OF SEED POTATOES IN TRANSIT
CAR I - COOL STORED, SHIPPED C.F.S., CHARCOAL HEATERS - STANDARD CAR
TEMPERATURE - DEGREES F.
40
50
60
70
80
90
Top layer
Middle layer
Bottom layer
LOADING
TRANSIT
STANDING
TRANSIT
UNLOADING
16
17
18
19
20
21
22
23
24
25
26
JANUARY